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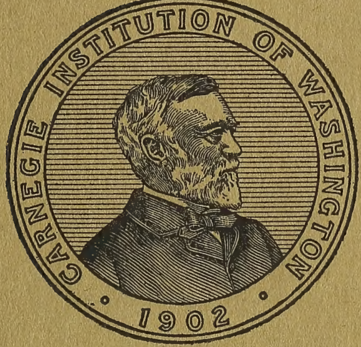

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III. A Miocene Mammalian Fauna from Southeastern Oregon. By C. Lewis Gazin. Pages 37 to 86, 6 plates and 20 text-figures.

IV. Additions to the Mammalian Fauna from the Tecuya Beds, California. By Chester Stock. Pages 87 to 92, 1 plate.

V. A New Genus of Otter from the Pliocene of the Northern Great Basin Province. By Eustace L. Furlong. Pages 93 to 103 and 2 plates.

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I

DISTRIBUTION AND AGE OF THE MARINE TERTIARY DEPOSITS OF THE COLORADO DESERT

By W. P. Woodring

With one figure

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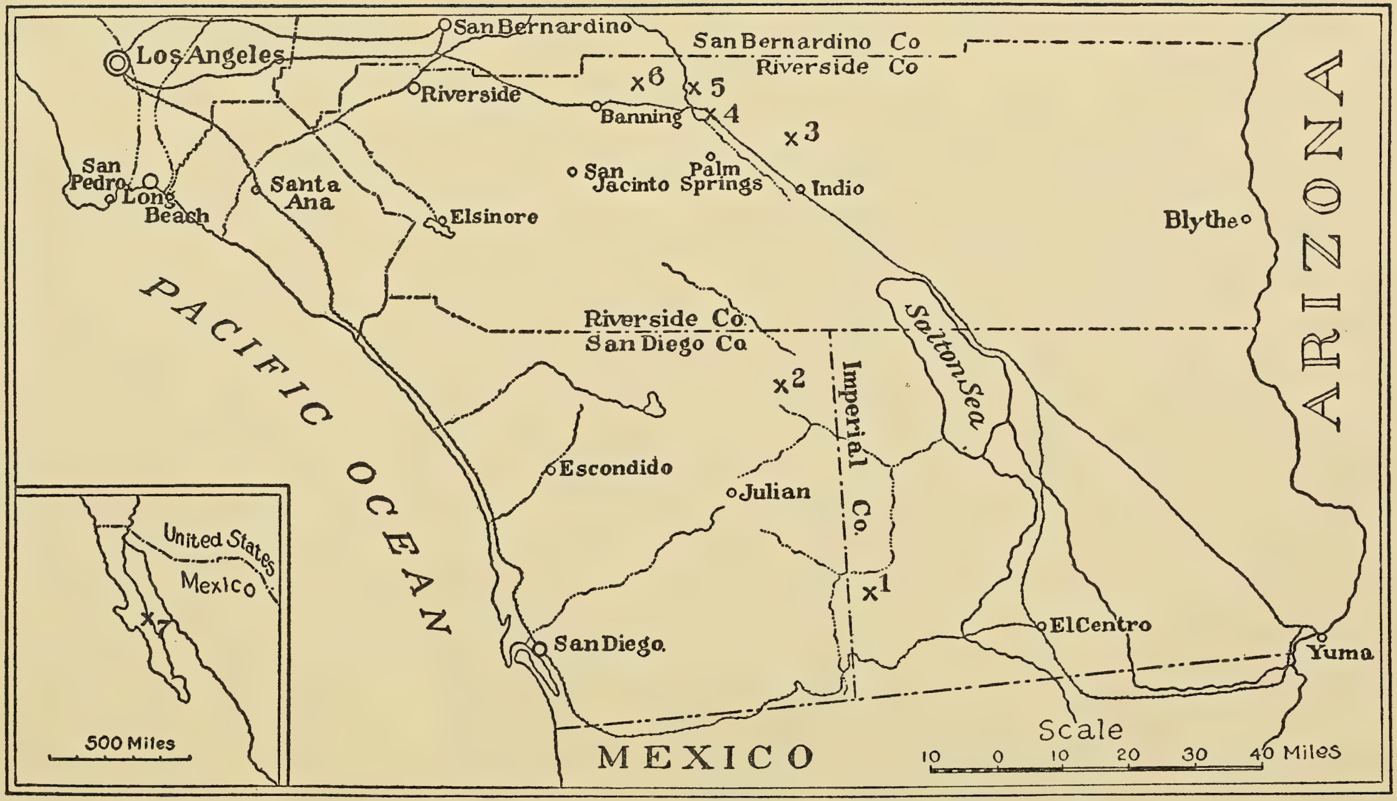

Fig. 1—Sketch maps of parts of Southern California and Mexico showing localities described.

DISTRIBUTION AND AGE OF THE MARINE TERTIARY DEPOSITS OF THE COLORADO DESERT

INTRODUCTION

The marine Tertiary beds of the great desert trough in which the Salton Sea lies have attracted attention ever since they were first discovered by Blake in 1853. Blake saw them as he was traveling down the west side of the desert from San Gorgonio Pass with the party of engineers to which he was attached. They have been most extensively explored around Carrizo Mountain, a spur extending eastward into the desert from the Peninsular Range close to the Mexican boundary. Many geologists have examined the region around Carrizo Mountain and the fossils found there have been described in many reports, but the lack of an adequate map has retarded detailed mapping and precise stratigraphic work of the kind that is required to fully decipher the geologic history. Dr. J. C. Merriam long ago recognized the critical position that this region holds in any attempt to establish a synchronization of events in the geologic history of California and tropical America. During the past few years I have carried on work there as part of a project sponsored by the Carnegie Institution of Washington and the California Institute of Technology. Through the cooperation of Mr. H. S. Gale, aeroplane photographs covering the eastern part of Carrizo Mountain were available during the winter of 1929-30. With these photographs as a base, detailed mapping was carried on in April 1930. The mapping is not yet complete, but the results obtained seem to justify this preliminary report, which also sets forth the discovery of the marine beds in other parts of the desert trough and its borders. I hope to complete the mapping and to prepare an account of the geology and also a critical review of the fossils.

I have greatly profited from discussions with Mr. Gale and with Professor A. O. Woodford, of Pomona College, who kindly criticized the discussion of the Tertiary vulcanism of parts of California adjoining this area. Mr. G. H. Anderson examined a specimen of the lava from Carrizo Mountain and Mr. D. D. Hughes identified several collections of foraminifera.

The name Colorado Desert is used for this region as I think it should be revived as a general regional name comparable with Mohave Desert. Unfortunately it has fallen into disuse and no other name except "Salton Sea region" or "Salton Basin," which are less satisfactory, has taken its place. Coachella Valley and Imperial Valley cover only part of the area.

DISTRIBUTION

CARRIZO MOUNTAIN AND VICINITY

(Locality 1, fig. 1)

Blake[1] followed the old road along Carrizo Creek three times. He saw or surmised the essential geologic features of the region. Anyone who knows the country and reads his pages must admire his keen observations and lucid, vivid descriptions, not only in this area but along other parts of the routes he covered. His description of wind action in San Gorgonio Pass and of the little pedicles of feldspar protected from wind erosion by tips of garnet ("pointing like jewelled fingers in the direction of the prevailing wind") is one of the most beautiful and inspiring that I know of in geological literature. Mendenhall's[2] and Kew's[3] accounts of the geology around Carrizo Mountain are the most detailed now available, but others have been issued by Fairbanks,[4] who made the first extensive explorations, Bowers,[5] Orcutt[6] and Brown.[7] The sketch maps by Kew and Brown are the only attempts at a geologic map published.

The oldest rocks on Carrizo Mountain are phyllite, mica schist, quartzite, schistose limestone and marble that are intruded by granitic and gabbro-like rocks. These metamorphics are intensely deformed and at places lie in great recumbent folds. They certainly are not younger than Paleozoic and in degree of metamorphism resemble Paleozoic rocks of the San Bernardino Range. Lying on the metamorphics and intrusives is a series of basalt flows, flow-breccias, tuffs, conglomerate and sandstone. Generally resting on the volcanics, but at places interbedded with them, are the marine deposits. I will return at greater length to the relation of volcanics and marine beds under the discussion of the age. Where the volcanics are absent the marine beds rest directly on the metamorphics.

[1] W. P. Blake, *Geological report, Williamson's Reconnaissance in California*, U. S. Pacific R. R. Expl. (U. S. 33d Cong., 2d sess., Senate Ex. Doc. 78 and House Ex. Doc. 91), vol. 5, pt. 2, pp. 89-105, 107-108, 120-122, 174-176, 1857.

[2] W. C. Mendenhall, *Notes on the Geology of Carrizo Mountain and Vicinity, San Diego County, California*, Jour. Geol., vol. 18, pp. 336-355, 1916.

[3] W. S. W. Kew, *Tertiary Echinoids of the Carrizo Creek Region in the Colorado Desert*, Univ. Calif. Pub. Bull. Dept. Geol., vol. 8, No. 5, pp. 39-60, 1914.

[4] H. W. Fairbanks, *Geology of San Diego County, also of Portions of Orange and San Bernardino Counties*, Calif. State Min. Bur., 11th Ann. Rpt. State Mineralogist, pp. 88-90, 1893.

[5] Stephen Bowers, *Reconnaissance of the Colorado Desert Mining District*, Calif. State Min. Bur., 19 pp., 1901.

[6] C. R. Orcutt, *The Colorado Desert*, West American Scientist, vol. 12, No. 1, pp. 2-14, 1901.

[7] J. S. Brown, *The Salton Sea Region, California*, U. S. Geol. Survey Water-Supply Paper 497, pp. 44-46, 1923.

The classification of the marine beds and overlying deposits here adopted and its relation to earlier arrangements are shown in the following table:

Classification of Tertiary marine beds and younger deposits of Carrizo Mountain and vicinity

Kew 1914		Hanna 1926	This report		Approximate thickness
Carrizo formation	?	?	Palm Spring formation (nonmarine): unconsolidated or poorly consolidated sands, light chocolate-brown and faint brick-red silts.		1000 feet (est.)
	Upper Division	Yuha reefs. Coyote Mountain clays	Imperial formation (marine)	Siltstone member: buff siltstone with occasional hard beds of very fossiliferous limy sandstone.	1400 feet
	Lower Division	Latrania sands Imperial formation		Basal member: conglomerate, sandstone, coralliferous limestone, and at places basalt flows and flow-breccias.	Few inches to 600 or 700 feet

The marine beds were first formally named by Kew,[1] who called them the "Carrizo formation" ("Carrizo Creek formation" is the form first used). Inasmuch as the name Carrizo sandstone was already in use for Eocene deposits in Texas,[2] as Vaughan [3] pointed out, Hanna [4] proposed Imperial formation as a substitute name. Unfortunately he also used the same name in a greatly restricted sense for the so-called coral reef in Alverson Canyon, and introduced additional names, as shown in the preceding table, for other parts of the section. The so-called coral reef is a lens in detrital deposits. For the part of these detrital deposits overlying the so-called reef, Hanna proposed the name "Latrania sands." This scheme would leave unnamed the beds below the so-called reef. Further objections to Hanna's nomenclature arise from the interbedding of the "Yuha reefs" at various horizons in the "Coyote Mountain clays." It is here proposed to simplify this nomenclature by using the name Imperial formation in Hanna's broad sense, but redefining it to embrace the entire series of marine deposits bordering Carrizo Mountain, and to exclude the overlying nonmarine beds. The Imperial formation as here redefined consists of a basal member and an overlying siltstone member. These subdivisions correspond to Kew's "Lower division" and "Upper division," except that there is nothing in his account to indicate that he did not also include in his "Upper division" at least the basal part of the nonmarine beds here named the Palm Spring formation.

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[1] W. S. Kew, loc. cit., p. 40, 1914.

[2] J. Owen, Texas Geol. Survey First Ann. Rpt., pp. 70, 73, 1889.

[3] T. W. Vaughan, U. S. Geol. Survey Prof. Paper 98, p. 357, 1917.

[4] G. D. Hanna, Proc. Calif. Acad. Sci., 4th ser., vol. 14, No. 18, p. 434, 1926.

The thickness and composition of the basal member of the Imperial formation are very variable. It may consist of only a few inches of limy sandstone or it may be made up of hundreds of feet of conglomerate and sandstone. Where it rests on the metamorphics, as near the head of Alverson Canyon on the south slope of Carrizo Mountain, the conglomerate is a mass of angular rubble that can hardly be distinguished from the dissected fan material that may overlie it. If the basement consists mostly of limestone, as near the east end of the mountain, the conglomerate is made up of limestone cobbles and blocks embedded in a limy matrix. The most curious conglomerate is the one that at places overlies the volcanics. It consists of closely spaced cobbles and boulders, or angular blocks, of basalt with a thin filling of limy matrix between them. This limy matrix has the appearance of calcite veinlets and the rock could readily be mistaken for an altered flow-breccia were it not for the fossils, many of which are large enough to completely fill the space between boulders. Cracks filled with the fossiliferous matrix extend down into the underlying basalt and it is difficult to determine just where the basalt ends and the conglomerate begins.

The conglomerate at many places grades upward into sandstone, with which limestone or limy sandstone carrying scattered heads and pieces of corals of reef facies may be interbedded, as in Alverson Canyon. I have not yet seen anything, however, that could properly be called a coral reef. Apparently most of the corals and other fossils in the coraliferous limestone in Alverson Canyon represent material that is not in the place where it grew. The oyster shells, which are far more abundant than corals in this bed, are badly worn. Fossils are to be found almost anywhere in the basal member except in most of the coarse conglomerate, but they generally are in a miserable state of preservation. The few accessible localities where good specimens can be obtained are pretty well cleaned out and new material weathers out slowly. A new locality recently discovered high on the crest of one of the main ridges yielded many fine specimens, but it already is in the class of places that are worked out.

The buff siltstone member conformably overlies the basal member with apparently no discontinuity. The basal member is so thin that the siltstone at many places seems to overlap it and to rest directly on the older rocks, but even at such places clean exposures show that the basal member, perhaps only a few inches thick, intervenes. Wherever the siltstone rests directly against the older rocks it is found to be in fault contact. Throughout the siltstone member are discontinuous beds of hard limy sandstone that form caps or dip slopes. These sandstones carry great numbers of a small oyster (called *Ostrea vespertina* Conrad since Conrad's day, but probably representing a different species), or of a small jingle shell (*Anomia subcostata* Conrad). A few small scallop shells (*"Pecten" deserti* Conrad) and an occasional large oyster (*Ostrea heermanni* Conrad) may also be found. Some beds are almost pure oyster reefs, others are virtually pure jingle shell reefs. The siltstone itself gives rise to intricately dissected areas and weathers to a dust-like powder that effectively mantles the rock. In fresh exposures it is seen to be a hard siltstone that readily disintegrates in water. Marine fossils have been found at different horizons in the siltstone from the base almost to the top, but they are not at all obvious and apparently are absent throughout hundreds of feet. Beds that seem to be barren are found to carry a few foraminifera and plant débris. Some of the siltstone fossils are the same as those found in the basal member; others are different, but the difference may be due principally to facies control. The thickest continuous section of siltstone in this region is one lying between Carrizo Creek and Fish Creek Mountain that Mr. Gale and I examined. The total computed thickness of siltstone in this section is 1250 feet, and the top is not exposed on account of faulting.

Clean contacts between siltstone and the underlying beds have not yet been seen, but the change takes place within a short interval. This considerable thickness of silt has some particular significance in the geologic history of the region. It is improbable that the material was suddenly furnished by the land areas that had been supplying the underlying coarse detrital débris. If this source is eliminated, the only apparent source is the ancient Colorado River; perhaps they represent the first recorded invasion of the Colorado into the Colorado Desert. This flood of silt, whatever its source, exterminated the corals and other sea animals that tolerate only clear water. The presence of normal marine fossils at different horizons shows that at times the salinity of the water was not lower than during the deposition of the basal member. The oyster reefs give an impression of brackish water, but so far as I know scallops and jingle shells do not tolerate water of low salinity. Perhaps the absence of fossils throughout a great part of the section may be attributed to particularly rapid increments of silt that smothered colonies that had succeeded in establishing themselves.

Conformably overlying the bluff siltstone with gradational contact are poorly consolidated or unconsolidated sands and silts of light shades of chocolate-brown and brick-red, which are well exposed in the vicinity of the ruins of the old stage station on Carrizo Creek. For these beds, which have an estimated thickness of 1000 feet, the name Palm Spring formation is proposed. This name is derived from the name of a spring along the lower part of Vallecito Creek, which is designated as the type region. Vallecito Creek is a southeastward-flowing tributary entering Carrizo Creek about a mile above the old stage station. These beds have the appearance of nonmarine deposits, but the lower part may have been laid down in brackish water. At all events Blake (p. 105) recorded the finding of a "*Gnathodon*" (a brackish-water matroid now known as *Rangia, R. lecontei* (Conrad)) in the "red strata" on Carrizo Creek where the road descends to the creek. Toward the mountains the Vallecito formation probably grades into fanglomerates.

WEST SIDE OF COLORADO DESERT BETWEEN FISH CREEK MOUNTAIN AND SANTA ROSA MOUNTAINS

(Locality 2, fig. 1)

Farther north along the west side of the desert is an extensive area for which only fragmentary information is available. I have not yet seen any part of it. Blake (p. 103) found specimens of "*Gnathodon*" *lecontei* along "Salt Creek" (San Felipe Creek?), and Kew (p. 44) found the same species north of Superstition Mountain. These records apparently indicate outcrops of the lower part of the Palm Spring formation. The marine beds proper may turn up anywhere in this area.

INDIO HILLS

(Locality 3, fig. 1)

Buwalda and Stanton[1] have recently recorded the presence of marine beds along the south edge of the Indio Hills, which lie along the east side of the desert. They were also discovered independently by H. S. Gale. The marine beds, consisting of buff siltstone like that in the siltstone member of the Imperial formation, are found in isolated patches both east and west of the entrance to Thousand Palms Canyon. They dip steeply into the hills and are overlain by coarse nonmarine beds, called the "Indio formation" by Buwalda and Stanton.[2] Even from the highway the buff color of the marine beds stands in marked contrast to the somber overlying land-laid deposits. Almost pure reefs of *Ostrea "vespertina"* lie in the upper part of the series. I have collected the following fossils from the marine beds without having exhausted the possibilities:

---

[1] J. P. Buwalda and W. L. Stanton, *Geological Events in the History of the Indio Hills and the Salton Basin, Southern California,* Science n. s., vol. 71, pp. 104-106, 1930.

[2] Unfortunately this name also is preoccupied, and by a curious coincidence it is in use for Eocene beds in Texas that lie in the same section as the Carrizo sandstone, a name that antedates "Carrizo formation," which Buwalda and Stanton use for the marine beds in the Indio Hills. I am indebted to Dr. T. W. Stanton for pointing out this earlier use.

Preliminary list of fossils from Indio Hills
(Calif. Inst. Tech. Loc. Nos. 187-191)

Gastropods:

Turritella imperialis Hanna
Vermetid?
"Cerithium"

Lamellibranchs:

Senilia
Ostrea "vespertina Conrad"
"Pecten" deserti Conrad?
Anomia subcostata Conrad?
"Crassatellites"
Macoma?
Tagelus?
Corbula

GARNET HILL

(Locality 4, fig. 1)

Garnet Hill is an isolated low hill lying along the westward extension of the Indio Hills, a few hundred yards east of Garnet, or Palm Spring Station as it formerly was called, on the Southern Pacific Railroad. I was guided to this locality by Mr. Richard Bramkamp, of Pomona College, who discovered marine fossils there while looking for minerals weathered out of schist boulders. We found no clean exposures on the entire hill. The surface is littered with the kind of rubble that weathers out of fanglomerates. The highway cut skirting the west end of the hill shows such débris embedded in caliche-soaked fine material. The following fossils were picked up on the south slope of the hill, either lying loose among the rubble or partly embedded in caliche.

Preliminary list of fossils from Painted Hill
(Calif. Inst. Tech. Loc. No. 192)

Lamellibranchs:

Ostrea heermanni Conrad
Pecten carrizoensis Arnold
"Pecten" purpuratus mendenhalli Arnold?
"Pecten" cf. sanctiludovici Anderson and Martin
"Pecten"
Spondylus

Echinoid:

Clypeaster

Though no outcrops can be seen, it is concluded that beds of the Imperial formation are in this hill and are masked by a veneer of fanglomerate, for some of the fossils are too perfect to have been transported as constituents of the fanglomerate and no boulders from which they might have weathered out were observed in the fanglomerate.

PAINTED HILL

(Locality 55, fig. 1)

At least two desert-rovers independently discovered marine Tertiary beds adjoining Painted Hill, a schist hill lying east of Whitewater River in the foothills north of the Colorado Desert. My attention was first drawn to this locality by Messrs. R. B. Peters and K. Garner, who showed me some fossils collected there by a friend from San Bernardino. Acting on this information Buwalda, Stanton and I found marine beds in the second canyon east of the river, where they are in contact with the schist, apparently along a high-angle thrust. Here the beds consist of buff micaceous siltstone and fine micaceous sandstone. They apparently grade upward into sandstone and fanglomerate, called Coachella fanglomerate by F. E. Vaughan.[1] Though Vaughan considered this fanglomerate of Quaternary age, it certainly is much older and occupies the same stratigraphic position as the "Indio formation." After visiting this region I found that Bramkamp had discovered other localities in the first canyon east of the river, where the marine beds consist of conglomerate, sandstone and siltstone. My collections from Painted Hill consist of the following species. Bramkamp, who has collected there repeatedly, has many others.

Preliminary list of fossils from Painted Hill

(Calif. Inst. Tech. Loc. Nos. 185, 186, 194, 195, 624)

Species marked with asterisk also represented in Miocene "clay shale," overlying sandstone referred to Vaqueros formation, as exposed in Los Sauces Canyon, Ventura County.

- Amphistegina cf. vulgaris d'Orbigny Hughes):
- Amphistegina cf. vulgaris d'Orbigny
- Bolivina cf. sp. from Los Sauces Canyon
- Bolivina
- Cassidulina cf. lævigata d'Orbigny
- *Cibicides americanus (Cushman)
- Cibicides cf. lobatus (d'Orbigny)
- Cibicides cf. floridanus (Cushman)
- Cibicides cf. conoideus Galloway and Wissler
- Discorbis
- Elphidium cf. crispum (Linné)
- Elphidium cf. granulosum Galloway and Wissler
- *Eponides
- Globigerina bulloides d'Orbigny
- Globigerina
- *Nonion?
- Planulina ariminensis d'Orbigny
- Quinqueloculina cf. seminulum (Linné)
- Quinqueloculina
- Robulus americanus spinosus (Cushman)
- Textularia
- *Uvigerina

Gastropods:
- Acmæa
- Calliostoma
- Naticoid
- Turritella imperialis Hanna
- Serpulorbis
- Nassarius?
- Conus
- Bulla

Scaphopod:
- Dentalium

Lamellibranchs:
- "Arca"
- Barbatia or Fossularca
- Glycymeris
- Altrina
- Ostrea
- "Pecten" purpuratus mendenhalli Arnold?
- "Pecten" 2 spp.
- Spondylus
- Lima?
- "Modiolus"?
- "Crassinella"
- Chama
- Trigoniocardia
- "Transennella"
- Antigona
- Solecurtus
- Corbula

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[1] F. E. Vaughan, *Geology of San Bernardino Mountains North of San Gorgonio Pass*, Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 13, No. 9, pp. 386-387, 1922.

These collections are particularly interesting for the large number of foraminifera and for the small genera of mollusks that are not represented in any collection from Carrizo Moutain. All the foraminifera listed are from one locality (194).

SAN GORGONIO PASS

(Locality 6, fig. 1)

F. E. Vaughan[1] announced in 1918 the discovery of marine beds along the north side of eastern San Gorgonio Pass. The few fossils that were found showed that these beds are of the same age as those around Carrizo Mountain. In his report on the geology of the eastern San Bernardino Mountains, Vaughan[2] named the fossiliferous bed the Lion sandstone. I visited with Bramkamp the branch of Lion Canyon described by Vaughan. We found no fossils in the sandstone that we took to be his Lion sandstone, but the following were collected in a siltstone cropping out on the left bank of the canyon about 100 feet below the outcrop of the sandstone. These beds dip steeply northward, and unless the section is overturned the siltstone underlies the sandstone.

Preliminary list of fossils from branch of Lion Canyon

(Calif. Inst. Tech. Loc. No. 193)

- Foraminifera:
  - Amphistegina
  - Quinqueloculina
- Coral:
  - Solenastrea
- Gastropod:
  - Turritella imperialis Hanna
  - Anachis?
- Plant:
  - Leaf imprint
- Lamellibranchs:
  - Anadara
  - Ostrea
  - "Pecten"
  - "Callocardia"
  - "Transennella"
  - Tellina
  - Macoma
  - Semele?

It should be noted that a piece of coral of reef facies and a leaf imprint were found in this siltstone.

No marine beds have been found farther west in San Gorgonio Pass, but the following fossils, collected by R. B. Moran in section 2, T. 3 S., R. 2 E., show that the fossiliferous siltstone crops out east of Lion Canyon:

Preliminary list of fossils from siltstone in sec. 2, T. 3 S., R. 2 E.

(Calif. Inst. Tech. Loc. No. 197)

- Gastropods:
  - Callistoma
  - Turritella imperialis Hanna
- Lamellibranchs:
  - Anadara
  - Pecten
  - "Pecten"
  - "Protocardia"
  - "Callocardia"
  - "Transennella"
  - Tellina
  - Semela?
  - Tagelus
  - Corbula
- Echinoid:
  - Clypeaster cf. deserti Kew

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[1] F. E. Vaughan, *Evidence in San Gorgonio Pass, Riverside County, of a late Pliocene Extension of the Gulf of California* (abstract), Bull. Geol. Soc. Amer., vol. 29, pp. 164-165, 1918.

[2] F. E. Vaughan, Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 13, No. 9, pp. 375-376, 1922.

SANTA ROSALIA, LOWER CALIFORNIA

(Locality 7, fig. 1)

Fossils resembling those from the Colorado Desert are recorded by Arnold [1] from Santa Rosalia, a mining district lying on the Gulf side of Lower California about halfway down the Peninsula. According to a recent account of the geology of the Santa Rosalia region, marine fossils are found in pyroclastics and other sediments overlying a lava described as an augite andesite.[2] The few fossils listed in this report (determinations by Grant) are not strongly suggestive of the Colorado Desert fossils and apparently are younger.

Three Carrizo Mountains Pectens (*Pecten carrizoensis* Arnold, *"Pecten" deserti* Conrad, and *"Pecten" mendenhalli* Arnold) are recorded from Santa Antonita Point, south of Santa Rosalia, from beds considered of upper Pliocene age.[3] These three species are closely allied to living ones.

AGE

The marine beds of the Colorado Desert have been called "doubtfully Cretaceous," Miocene and Pliocene. The earliest opinion by T. W. Vaughan [4] that the corals discovered by Fairbanks indicated a doubtful Cretaceous age was soon abandoned. Arnold [5] first called them lower Miocene, or simply Miocene, but later,[6] on considering that one of the fossils, *"Pecten" deserti,* was represented in the Etchegoin formation of the San Joaquin Valley, referred them to the upper Miocene. Inasmuch as the Etchegoin formation is now considered of Pliocene age, this was the first assignment to the Pliocene. According to Kew,[7] the echinoids indicate a "comparatively late age," later [8] called Pliocene. Vaughan's [9] final opinion on the corals was that "lower Pliocene appears to be the maximum age which may be assigned to the fauna." After examining the mollusks, Hanna [10] concurred in regarding the beds as Pliocene and even considered the greater part of the series as middle and upper Pliocene. At a late date, however, Dickerson[1] again called attention to the Caribbean Miocene affinities of the fauna.

---

[1] Ralph Arnold, *The Tertiary and Quaternary Pectens of California,* U. S. Geol. Survey Prof. Paper 47, pp. 84-85, 1906.

[2] M. E. Touwaide, *Origin of the Boleo Copper Deposit, Lower California, Mexico,* Econ. Geol., vol. 25, No. 2, pp. 113-114, 1930.

[3] G. D. Hanna and L. G. Hertlein, Proc. Calif. Acad. Sci., 4th ser., vol. 16, No. 6, pp. 144-145, 1927

[4] T. W. Vaughan, U. S. Geol. Survey Mon. 39, p. 19, 1900.

[5] Ralph Arnold, Science n. s., vol. 19, p. 503, 1904; U. S. Geol. Survey Prof. Paper 47, p. 21, 1906.

[6] Ralph Arnold, U. S. Geol. Survey Bull. 396, p. 44, 1909.
Ralph Arnold and Robert Anderson, U. S. Geol. Survey Bull. 398, p. 139, 1910.

[7] W. S. W. Kew, Univ. Calif. Pub. Bull. Dept. Geol., vol. 8, No. 5, p. 46, 1914.

[8] W. S. W. Kew, Univ. Calif. Pub. Bull. Dept. Geol., vol. 12, No. 2, pp. 32, 33, 56, 59, 60, 61, 137, 1920.

[9] T. W. Vaughan, U. S. Geol. Survey Prof. Paper 98, p. 368, 1917.

[10] G. D. Hanna, *Paleontology of Coyote Mountain, Imperial County, California,* Proc. Calif. Acad. Sci., 4th ser., vol. 14, No. 18, p. 434, 1926.

EVIDENCE FROM HISTORY OF VULCANISM

The volcanic rock of Carrizo Mountain is an olivine basalt, according to G. H. Anderson, of the California Institute of Technology, who kindly examined a specimen from Alverson Canyon. His description of the rock is as follows:

> "The rock is dark reddish gray and carries phenocrysts of altered olivine in a fine-grained holocrystalline groundmass composed essentially of laths of plagioclase and abundant prisms of augite. Extinction angles that could be measured indicate that the plagioclase is labradorite. The augite occurs principally in very pale green to colorless prisms that have almost no pleochroism, and also as irregularly shaped grains. Numerous minute grains of magnetite or ilmenite are scattered through the specimen. A few grains of titanite and a little zircon were recognized. Biotite is absent or very rare.
>
> "The phenocrysts originally were olivine, but are greatly altered. They are mostly in euhedral crystals of varying size. On the margins and along cleavage planes the original mineral has been changed to iron oxides. In the interior, alteration has produced a fibrous, almost colorless weakly pleochroic mineral of moderate birefringence, probably closely allied to chrysotilite. Hornblende and chlorite appear less frequently as alteration products.
>
> "In contrast to the extremely altered condition of the phenocrysts, the groundmass presents a relatively fresh appearance. Within the groundmass the ferromagnesian minerals appear to be in somewhat greater amount than the feldspar, and they are in considerable excess, taking into account the phenocrysts."

Both Mendenhall and Kew have described the occurrence of sediments under the lava. At most localities examined these beds appear to be land-laid. They consist of reddish and greenish sandstone, conglomerate and tuff. On the southeast slope of Carrizo Mountain, particularly in the area drained by the first big canyon southwest of Painted Gorge, into which a tourist-frequented road runs, the basal marine beds are interbedded with the basalt. In this area three or four beds of sandstone carrying marine fossils lie between and interfinger with basalt. The upper surface of each sandstone bed is altered to a quartzite that is as hard and as ancient-looking as the quartzite in the basement complex. The best collection of fossils so far obtained came from the lower unaltered part of one of these beds. Some of the quartzites form great dip slopes, one of which is a conspicuous feature as Carrizo Mountain is passed on the San Diego highway. It is so dark and rough-looking that I had assumed that it was a lava flow. No evidence was seen indicating that the basalt flowed into the sea, though no extensive search was made to find such evidence. At other places nearby, the basal marine bed lies on an eroded surface of lava and is made up principally or solely of material derived from it. This relation and the interbedding of lava and marine beds indicate that the region was close to sea-level during the period of vulcanism, and the lava-covered sandstones may have been above sea-level when the lava flowed over them.

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[1] R. E. Dickerson, *Mollusca of the Carrizo Creek beds and their Carribean Affinities* (abstract), Bull. Geol. Soc. Amer., vol. 29, p. 148, 1918.

At Santa Rosalia marine beds, composed largely of tuffaceous material and probably of the same age as those at Carrizo Creek, overlie a lava described as an augite andesite.

The lava of Carrizo Mountain apparently represents the period of vulcanism that began in lower Miocene time, the effects of which are wide-spread in southern California and adjoining regions. If this vulcanism were limited to a short interval of geologic time it would afford a means in establishing synchronization more precise than a good many paleontologic zones, but unfortunately it is not. According to published accounts, the lavas in the Mohave Desert,[1] at the south end of the San Joaquin Valley,[2] in the Cuyama Valley,[3] and farther south in Southern California,[4] range in age from lower Miocene to Pliocene or even Quaternary. Evidence pointing to a much earlier period of vulcanism during Martinez (Paleocene) time in Southern California has recently been found in the Elsinore Valley by J. C. Sutherland, of the California Institute of Technology. The stratigraphic succession at Carrizo Mountain more closely parallels the sequence at the south end of the San Joaquin Valley than in any other area in Southern California where lavas and marine beds are found in the same section, as is shown in the following summary:

Comparison of stratigraphic succession at Carrizo Mountain and south end of San Joaquin Valley

Carrizo Mountain	*South end of San Joaquin Valley*
Marine beds of Imperial formation overlying or interbedded with basalt.	Marine beds referred to Vaqueros formation overlying or interbedded with basalt.
Basalt.	Andesite followed by basalt, or basalt only.
Land-laid conglomerate, sandstone, and tuff.	Land-laid Tecuja beds of Stock.[5]

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[1] C. L. Baker, *Notes on the Later Cenozoic History of the Mohave Desert Region in Southeastern California,* Univ. Calif. Pub. Bull. Dept. Geol., vol. 6, No. 15, pp. 333-383, 1911.

C. D. Hulin, *Geology and Ore Deposits of the Randsburg Quadrangle, California,* Calif. State Min. Bur. Bull. 95, pp. 42-60, 1925.

[2] R. W. Pack, *The Sunset-Midway Oil Field, California,* U. S. Geol. Survey Prof. Paper 116, pp. 52-53, 1920.

H. W. Hoots, *Geology and Oil Resources along the Southern Border of San Joaquin Valley, California,* U. S. Geol. Survey Bull. 812, pp. 258-265, 1930.

[3] W. A. English, *Geology and Oil Prospects of Cuyama Valley, California,* U. S. Geol. Survey Bull. 621, p. 205, 1916.

[4] W. S. W. Kew, *Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California,* U. S. Geol. Survey Bull. 753, pp. 91-93, 1924.

W. A. English, *Geology and Oil Resources of the Puente Hills Region, Southern California,* U. S. Geol. Survey Bull. 768, pp. 46-47, 1926.

A. O. Woodford, *The San Onofre Breccia, its Nature and Origin,* Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 15, No. 7, pp. 178-179, 1925.

[5] Chester Stock, *An Early Tertiary Vertebrate Fauna from the Southern Coast Ranges of California,* Univ. Calif. Pub. Bull. Dept. Geol., vol. 12, No. 4, pp. 267-276,. 1920.

The temptation to generalize from this parallelism is inviting, but the probability that the parallelism itself has any age significance is very remote. About the best that can be said for the lava is that on the assumption that it represents the most wide-spread period of vulcanism in Southern California it fixes the lower age limit for the Imperial formation as lower Miocene; it might represent any part of the Miocene, or Pliocene, or even Quaternary. The basaltic composition perhaps favors a time later than the very beginning of the period of vulcanism, as the more acid lavas of this Miocene-Quaternary group of volcanics generally are earlier than the basic ones.

DIASTROPHIC EVIDENCE

Even in a region so unstable as California some time significance may be attributed to extensive floodings by the sea in different regions. Aside from the partial flooding of the San Joaquin Valley, the Pliocene seas were limited to relatively small coastal basins. The lower Miocene Vaqueros sea represents a pronounced transgression following a long period of emergence. This feature is clearly brought out in the forthcoming study of the Vaqueros formation by Arnold, Loel and Corey, in which they are assembling in the most painstaking manner everything that is known about the formation and its fossils. At many places the Vaqueros lies on or begins with red beds, which represent material accumulated during the period of emergence or reworked from it. This long period of emergence accounts for the strikingly meager record of marine Oligocene deposits in California. Part of what has been called Oligocene is Eocene,[1] and the San Ramon formation of B. L. Clark with its modernized fauna looks suspiciously like Miocene.[2] This line of evidence lends further support to the possible age significance of the parallelism between the sections at Carrizo Mountain and the south end of the San Joaquin Valley, but is by no means conclusive.

The middle Miocene transgression was even more extensive than the Vaqueros one, but only a short interval of emergence intervened and at places there was none. Extensive land-laid beds at the base of the middle Miocene Temblor formation are rare, except at the localities where virtually all the underlying Vaqueros consists of nonmarine deposits. Likewise the upper Miocene sea covered a still greater area, but land-laid beds are absent beneath the deposits laid down in it, except at the margin of a basin, as in the Cuyama Valley.

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[1] W. P. Woodring, *Upper Eocene Orbitoid Foraminifera from the Western Santa Ynez Range, California, and their Stratigraphic Significance,* Trans. San Diego Soc. Nat. Hist., vol. 6, No. 4, pp. 145-170, 1930.

[2] The modernization of the marine Miocene fauna is clearly brought out by Dr. A. Morley Davies in his recent presidential address before the Geologists' Association. (*Faunal Migrations since the Cretaceous Period,* Proc. Geol. Assoc., vol. 40 [1929], pp. 307-327, 1930.)

The Miocene affinities of the San Ramon fauna have been discussed by Stewart in a report that was issued after this paper was written. (R. B. Stewart, *Gabb's California Cretaceous and Tertiary Type Lamellibranchs,* Acad. Nat. Sci. Phila., Special Pub. No. 3, pp. 19-20, 1930.)

Diastrophic grounds favor a Miocene age rather than a Pliocene, and if the long period of emergence attested to by the absence of any earlier marine Tertiary beds and by the presence of land-laid deposits below the lavas corresponds to the longest general period of Tertiary emergence in the Coast Ranges, it points to a lower Miocene age.

PALEONTOLOGIC EVIDENCE

No matter what period of geologic time is represented by these deposits, the fauna that they carry is unlike any in the Coast Ranges, for it represents a different faunal region. This feature is responsible in large measure for the widely varying views that have been held as to the age, and indicates that there was no connection between the head of the embayment and the Coast Ranges. Nevertheless it should be possible to find some phyla that are represented both in the Colorado Desert embayment and in the Coast Ranges or on the outer side of Lower California, just as some modern phyla are found in both regions. If the marine beds of the desert are Pliocene, at least a few closely allied species should be found in one or more of the Pliocene faunas in Southern California and Lower California. No close affinities are apparent in the lower Pliocene fauna found in Elsmere Canyon near Newhall. Aside from the record of *Clypeaster deserti* Kew and *"Pecten" mendenhalli* Arnold at Cedros Island, off Lower California,[1] the middle or upper Pliocene San Diego fauna, which is found as a distinct and readily recognized warm-water faunal zone from Lower California to the Ventura Basin,[2] also holds no close resemblances. Both Carrizo Mountain species recorded from Cedros Island closely resemble living ones and it is doubtful whether much weight can be attached to them unless no other close affinities can be found. It is hardly necessary to consider any younger deposits, for I think no one would seriously consider that the marine beds of the Colorado Desert are younger than the San Diego formation. Nor is it necessary to consider the Jacalitos or Etchegoin formations of the San Joaquin Valley. The evidence on which Arnold concluded that the Carrizo Mountain fossils bore some resemblance to those of the Etchegoin formation is too slender and has for the most part already been disposed of.

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[1] E. K. Jordan and L. G. Hertlein, Proc. Calif. Acad. Sci., 4th ser., vol. 15, No. 14, pp. 416, 419, 1926.

An undetermined coral of the genus *Solenastrea* is recorded from the Pliocene of Maria Madre Island (E. K. Jordan and L. G. Hertlein, Proc. Calif. Acad. Sci. 4th ser., vol. 15, No. 4, p. 211, 1926).

[2] W. P. Woodring, *Pliocene Deposits North of Simi Valley, California,* Proc. Calif. Acad. Sci., 4th ser., vol. 19, No. 6, pp. 57-64, 1930.

If no marked Pliocene affinities are apparent, the question arises as to whether any Coast Range Miocene affinities can be recognized. Arnold suggested a lead when he listed "*Turritella* (cf.) *hoffmanni* Gabb" from Carrizo Mountain.[1] It had never occurred to me that this *Turritella,* named *T. imperialis* by Hanna, was allied to *T. inezana* Conrad, an earlier name for the species Gabb called *hoffmanni,* until W. H. Corey, of the University of California, orally pointed out its striking resemblance to "frilled" forms of *inezana* that he is describing in collaboration with W. F. Loel in their monograph of the Vaqueros fauna. If this resemblance is due to actual genetic affinity instead of to homeomorphy, other Vaqueros resemblances should be apparent. Another can be seen in the resemblance of a large undescribed *"Pecten"* to *"Pecten" magnolia* Conrad, another characteristic Vaqueros fossil, though the resemblance is not so striking as in the case of the *Turritella.* Another is apparent in the resemblance on a small scale of *Ostrea lœli* Hertlein to *O. heermanni* Conrad. This is a short list, but it embraces two extinct phyla and it is very suggestive in the absence of any comparable Pliocene affinities.

Nothing is strongly suggestive of the middle Miocene fossils of the Coast Ranges. So long as the genus *Turritella* is represented, a middle Miocene Gulf of California fauna would be expected to include the phylum of *Turritella ocoyana,* which is found in Lower California and southward into the tropics on both the Pacific and Atlantic sides.[2] Though such negative evidence is untrustworthy, some Coast Range middle Miocene stocks should be represented.

Likewise nothing definitely suggests Coast Range upper Miocene. The Santa Margarita species *"Pecten" sanctiludovici* Anderson and Martin, recorded by Hanna from Carrizo Mountain, represents a wide-spread group of Pectens, the species of which may not be intimately allied. *"Pecten" mediacostatus* Hanna is described as resembling *"Pecten" estrellanus* Conrad, which has a considerable range through the Miocene and into the Pliocene. The Vaqueros and Temblor species *"Pecten" miguelensis* Arnold belongs to this group of Pectens.

I have always been impressed with the Miocene aspect of this fauna, but I have been unwilling to entirely trust my judgment for fear it might be somewhat distorted by long familiarity with Caribbean Miocene faunas. Caribbean Miocene affinities are unmistakable in the fossils from Carrizo Mountain, as Dickerson and others have pointed out, but these affinities alone are not conclusive evidence that the fauna is Miocene, for such affinities also are unmistakable in the present fauna of the Gulf of California and the coast of Mexico and Central America farther south. The Mazatlantic and Panamic regions harbor the end members of many Caribbean Miocene phyla. Though this feature must be kept in mind, certain phyla that are extinct along the Pacific Coast deserve special consideration. *Turritella imperialis* represents one of them. It closely resembles, as everyone has recognized, *T. altilira* Conrad, of the middle Miocene Gatun formation of Panama and Costa Rica, and the closely allied forms found in the Miocene of the Caribbean region, for which far too many names have been proposed. This phylum is wide-spread in Caribbean lower Miocene deposits (Anguilla, Haiti, Dominican Republic, Costa Rica, Panama, Colombia, Venezuela, Trinidad) and during middle Miocene time its distribution was even more extensive (Dominican Republic, Jamaica, Costa Rica, Panama, Colombia, Venezuela, Trinidad, Peru, Pacific coast of Panama). A species in the upper Miocene Cerros de Sal formation of the Dominican Republic is the last representative in the tropics, but a Pliocene species from Florida, *T. perattenuata* Heilprin, is regarded as the final member. If these Caribbean Turritellas and *inezama* are derived from the same stock, as Corey believes and as seems reasonable, it may be significant that of all the Caribbean representatives *T. crocus* Cooke,[1] from the Anguilla formation of the island of Anguilla, is most like *inezana s. s.* If this evidence furnished by one phylum means anything, it is a clear indication as to what part of the lower Miocene is represented by the Vaqueros formation. The Anguilla formation embraces the oldest Miocene zone now recognized in the Caribbean region and is considered of Aquitanian age.

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[1] Ralph Arnold, U. S. Geol. Survey Prof. Paper, 47, p. 22, 1906.

[2] W. P. Woodring, *Miocene Mollusks from Bowden, Jamaica, Pt. 2: Gastropods and Discussion of Results,* Carnegie Inst. Wash. Pub. No. 385, pp. 96, 98, 1928.

Distribution in tropical America of Turritellas of the Phylum of Turritella ocoyana (abstract), Bull. Geol. Soc. Amer., vol. 40, No. 1, pp. 256-257, 1929.

A Carrizo Mountain cone, called *Conus regularis* Sowerby by Hanna, closely resembles *C. proteus* Hwass, a living West Indian species that is found as far back as the middle Miocene, and doubtfully in the lower Miocene. Like the Caribbean Miocene specimens those from Carrizo Mountain retain, with unusual perfection, the color pattern of many spiral rows of small, rectangular, brown blotches.[2] Mr. E. G. Vanatta, of the Philadelphia Academy of Natural Sciences, kindly confirmed my impression that no cone closely resembling *proteus* is recorded as living along the Pacific Coast of America. This fossil species is more similar to *proteus* than it is to *C. regularis* Sowerby, *C. scalaris* Valenciennes, and *C. gradatus* Mawe, all of which are living Pacific Coast species. Mr. Vanatta reminded me that Dall [3] had specimens of *C. proteus* from the Pacific Coast of

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[1] C. W. Cooke, Carnegie Inst. Wash. Pub. No. 291, p. 121, pl. 4, fig. 8, 1919.

[2] W. P. Woodring, Carnegie Inst. Wash. Pub. No. 385, pp. 204-205, 1928.

[3] W. H. Dall, *Summary of the Shells of the Genus Conus from the Pacific Coast of America in the U. S. National Museum,* Proc. U. S. Nat. Mus., vol. 38, p. 227, 1910.

Panama, but that he considered the locality record erroneous. I remember these specimens in the West Coast collections of the United States National Museum labeled "Panama ?." The possibility of *proteus* living in the Panamic region can not be lightly dismissed, for any living species that is found as far back as Miocene time is likely to be established now on both sides of Central America.

The most striking example of Caribbean affinities, involving the extinction on the Pacific Coast of a genus, is afforded by *Cassis*. This genus has a long history in West Indian and Floridian waters, extending from middle Oligocene time to the present. The Carrizo Mountain species, *C. subtuberosa* Hanna, is the only one, recent or fossil, from the entire Pacific Coast of America. It represents a clear case of a migrant from the West Indies that gained a temporary foothold in the eastern Pacific.

In addition to these few species, which represent extinct, or apparently extinct, phyla, so far as Pacific waters are concerned, many other Carrizo Mountain fossils are similar to Miocene species from the Caribbean region, including several genera and groups of species that are extinct in the Caribbean Sea (*Malea, Solenosteira,* group of *Cancellaria obesa* Sowerby, group of *Conus fergusoni* Sowerby, group of *Ficus decussata* (Wood)). In fact, no species, so far known, in the Imperial formation would be out of place in a Caribbean Miocene fauna.

If the Caribbean Miocene affinities mean free faunal migration between the two regions—and they clearly do—when did the migration take place? It is well known from areal geology and from the distribution of sea and land animals, that the sea extended across parts of Central America during lower and middle Miocene time, but there is no clear evidence for later interoceanic communication. The extinct phyla discussed and many others represented in the Imperial formation are known to have been living in the Caribbean region when the seas were in communication. It does not necessarily follow, that the beds of the Colorado Desert are Miocene, for these animals might have migrated from the Caribbean Sea into the Pacific, or in the opposite direction, during Miocene time and still survive until Pliocene time in the Gulf of California. According to my experience, however, many marine migrants lose their foothold in the region to which they have migrated when communication with the area from which they have come is broken, not because a constant stream of newcomers is required to keep up the stock, but because the closing of such communications has a profound effect on oceanic circulation, which represents a delicate adjustment of an intricate series of interrelated factors. This disarrangement of oceanic circulation and the resulting upsetting of oceanographic equilibra seems adequate to account for the extinction of animals that failed to become adjusted to the change. Why some animals should succeed and others fail is a question that is shrouded in mystery. This clearly is the sequence of events in the wholesale extinction of genera among many kinds of marine invertebrates in the Caribbean Sea toward the close of Miocene time, an extinction for which I have suggested that one factor alone—temperature—may be responsible,[1] but that solution is inadequate and far too simple. If this line of reasoning is accepted, it is improbable that the extinct Caribbean migrants survived until Pliocene time. If the fauna is Miocene, the percentage of mollusks referred by Hanna to species living in the Gulf of California (65 per cent), is much too high.[2] Perhaps this figure is not to be taken too seriously, for only a small part of the fauna then living is represented and much of the material studied is poorly preserved. The small genera from Painted Hill now being examined by Bramkamp may considerably change the percentage.

T. W. Vaughan has shown that the corals have even more unmistakable Caribbean affinities. All six genera represented in the Imperial formation are now living in the Caribbean Sea and Gulf of Mexico, but only one (*Porites*) is living in the eastern Pacific. On account of the resemblance to Pliocene and Recent Floridian and West Indian species and on account of the absence of West Indian Miocene genera now living in Indio-Pacific waters (*Stylophora, Pocillopora* and *Goniopora*) Vaughan concluded that the corals could not very well be older than Pliocene and that they indicated a late Tertiary communication with the Gulf of Mexico after the entinction there of the Miocene Indo-Pacific genera. Perhaps the evidence can be analyzed further, particularly in view of later information derived from exploration of the rich Miocene coral reefs of Haiti and the Dominican Republic. These data are summarized in the table on page 23.

It will be seen from this tabulation, that not only all the genera represented in the Imperial formation were living in the West Indies during lower or middle Miocene time, but that at last five of the eight species with which the Imperial corals are closely allied were living then. These new records effectively break down the marked Pliocene affinities of the Imperial coral fauna. They do not in themselves demonstrate that the fauna is of Miocene age, though they support such a view. If the same line of reasoning is applied to the

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[1] W. P. Woodring, Carnegie Inst. Wash. Pub. No. 385, pp. 28-29, 1928.

Stewart has recently emphasized the inadequacy of the temperature factor. (R. B. Stewart, Acad. Nat. Sci. Phila., Special Pub. No. 3, p. 24, 1930.)

[2] For figures covering a number of Miocene faunas see Woodring, Carnegie Inst. Wash. Pub. No. 385, pp. 106-107, 1928.

Corals from Imperial formation and most closely allied species

Species from Imperial formation	Most closely allied species, all from Florida or West Indies (Vaughan 1917,[1] 1919 [2])	Earliest appearance in West Indies of most closely allied species or of a similar one [3]
Eusmilia carrizensis Vaughan	E. fastigiata (Pallas), Plioc., Rec.	E. sp., undetermined part of Yaque group (lower or middle Miocene), Dominican Republic.
Dichocœnia merriami (Vaughan) var. crassisepta (Vaughan)	D. sp. Plioc.; D. stokesi Milne Edwards and Haime, Rec.	D. stokesi, Las Cahobas formation (early middle Miocene), Haiti.
Solenastrea fairbanski (Vaughan) var. columnaris (Vaughan) var. normalis Vaughan var. minor Vaughan	S. hyades (Dana) and S. bournoni Milne Edwards and Haime, Plioc., Rec.	S. hyades, Las Cahobas formation (early middle Miocene), Haiti. S. bournoni, Thomonde formation (late lower Miocene), Haiti.
Mæandra bowersi Vaughan	M. labyrinthiformis (Linné) Plioc., Rec.	M. aff. labyrinthiformis, "probably Oligocene" (lower Miocene?), Dominican Republic.
Siderastrea mendenhalli Vaughan	S. dalli Vaughan, Plioc., and S. siderea (Ellis and Solander), Rec.	S. siderea, Thomonde formation (late lower Miocene), Haiti.
Siderastrea californica Vaughan	S. pliocenica Vaughan, Plioc., and S. radians (Pallas), Rec.	S. radians, Artibonite group (probably early middle Miocene part), Haiti.
Porites carrizensis Vaughan	P. astreoides Lamarck, Plioc., Rec.	P. aff. astreoides, lower or middle Miocene, Trinidad; Artibonite group (probably early middle Miocene part), Haiti.

[1] T. W. Vaughan, U. S. Geol. Survey Prof. Paper 98, pp. 355-395, 1917.

[2] T. W. Vaughan, U. S. Nat. Mus. Bull. 103, pp. 223-224, 1919.

[3] Data after Vaughan in following reports: T. W. Vaughan and W. P. Woodring, Tertiary and Quaternary Stratigraphic Paleontology, Dom. Rep. Geol. Survey Mem., vol. I, pp. 89-168, 1921; W. P. Woodring, J. S. Brown, and W. S. Burbank, Geology of the Republic of Haiti, Rep. Haiti Geol. Survey, pp. 178-218, 1924; T. W. Vaughan and J. E. Hoffmeister, Miocene Corals from Trinidad, Carnegie Inst. Wash. Pub. No. 344, 105-134, 1926.

corals as to the mollusks, the probability is that they are not younger than Miocene. If they are Miocene, it seems strange that *Stylophora, Pocillopora, Asterosmilia, Antillia* and *Gonipora* are not represented, though their absence is not conclusive evidence that the age is not Miocene.

According to Kew, four of the five species of echinoids closely resemble living species from the Gulf of California, whereas the fifth, *"Clypeaster" carrizoensis* Kew has a doubtful resemblance to *"Scutella" gabbii* (Rémond), from the lower part of the San Pablo series of B. L. Clark. Hanna has added a sixth doubtfully determined species, *Metalia spatagus* (Linné)?, which is living in the Gulf. If the Imperial echinoids show that the beds are Pliocene, as

Kew maintained, the Gatun echinoids show that the Gatun formation is Pliocene, though a middle Miocene age for the Gatun formation is accepted by all the modern workers, both American and European. Aside from a *Schizaster,* the Gatun echinoids, representing the genera *Clypeaster* and *Encope,* are very much like species from the Imperial formation, as Jackson has pointed out.[1] It should also be noted that "*Clypeaster* aff. *deserti* Kew" is recorded from the Miocene of Lower California.[2]

The foraminifera furnish additional paleontological evidence that heretofore has not been considered. In addition to identifying the material from Painted Hill already listed, Mr. D. D. Hughes has kindly examined a sample collected near the base of the siltstone member of the Imperial formation on the north slope of Carrizo Mountain. This collection consists of the following species:

Preliminary list of foraminifera collected near base of siltstone member of Imperial formation

(Field No. 7-7-1; identified by D. D. Hughes)

Species marked with asterisk also represented in the Miocene "clay shale," overlying sandstone referred to Vaqueros formation, as exposed in Los Sauces Canyon, Ventura Co.

Buliminella
Cibicides cf. floridanus (Cushman)
Guadryina
*Guttulina
Haplophragmoides?
Lagena cf. melo (d'Orbigny)
*Lagena
*Nonion cf. incisum (Cushman)
Planulina cf. ariminensis d'Orbigny
*Tritaxia cf. pyramidata Reuss
Textularia
*Valvulineria

Another sample, from a horizon lying several hundred feet above the base of the siltstone member, carries only one species, *Elphidium* cf. *hughesi* Cushman and Grant.

According to Mr. Hughes, this fauna, like the one from Painted Hill, is different from any in the coastal region, but several of the species, or a number of similar ones, are found in the "clay shale" that overlies sandstone referred to the Vaqueros formation, as exposed in Los Sauces Canyon, Ventura County. The "clay shale" is considered of late lower or early middle Miocene age. The *crispum*-like and *granulosum*-like species of *Elphidium* give the fossils a late Pliocene or Pleistocene appearance in terms of the succession of foraminiferal faunas in the Los Angeles and Ventura Basins, but such species are found as far back as the lower Miocene in the West Indies and Florida. Likewise the *Elphidium,* similar to *E. hughesi,* may indicate brackish water, rather than the Pliocene age that is generally associated with it. Of the described Caribbean and Floridian fossil foraminifera, Mr. Hughes considers that those from the upper Miocene Choctawhatchee formation of Florida show the closest affinity to the fossils from the Colorado Desert. It should be pointed out, however, that the foraminifera of a great many West Indian Miocene deposits have not yet been described.

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[1] R. T. Jackson, *Fossil Echini of the Panama Canal Zone and Costa Rica,* Proc. U. S. Nat. Mus., vol. 53, 489-501, 1917; U. S. Nat. Mus. Bull. 103, pp. 103-116, 1919.

[2] L. G. Hertlein and E. K. Jordan, *Paleontology of the Miocene of Lower California,* Proc. Calif. Acad. Sci., 4th Ser., vol. 16, No. 19, pp. 607, 611, 1927.

CONCLUSIONS AS TO AGE

The paleontological evidence points to the conclusion that the marine beds of the Colorado Desert are of Miocene age, and the other two lines of evidence passively support this conclusion. There is little on which to base a conclusion as to what part of the coastal Miocene section is represented, but the evidence that is now apparent indicates late Vaqueros age; that is, late lower Miocene. According to this view, if vertebrate remains are found in the nonmarine beds underlying the basalt, they would correspond in age to those from the Tecuja beds of Stock, at the south end of the San Joaquin Valley. If they are found in the Palm Spring formation, they would be of Temblor or Barstow age. The "Indio formation" and "Coachella fanglomerate" occupy the same stratigraphic position with reference to the marine beds as the Palm Spring formation, but as both are closer to the head of the trough, their base may lie at a lower horizon.

This region is an interesting one, not only on account of its fascinating marine fauna, but also because it offers the opportunity to establish a time scale at a place where marine beds and land-laid deposits are found in superposition. Such places are all too rare in California.

II

DISTRIBUTION AND DESCRIPTION OF SKULL REMAINS OF THE PLIOCENE ANTELOPE SPHENOPHALOS FROM THE NORTHERN GREAT BASIN PROVINCE

By Eustace L. Furlong

With five plates and one text-figure

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DISTRIBUTION AND DESCRIPTION OF SKULL REMAINS OF THE PLIOCENE ANTELOPE SPHENOPHALOS FROM THE NORTHERN GREAT BASIN PROVINCE

INTRODUCTION

With the progress of paleontological explorations in the later Tertiary deposits of the northern Great Basin Province by the California Institute of Technology in cooperation with Carnegie Institution of Washington additional materials of the antilocaprid genus *Sphenophalos* have been found. Of particular interest is the discovery of remains of this mammal in new Pliocene faunas of eastern Oregon, thus extending the known range of *Sphenophalos.* While no complete skull is available, the specimens collected include a number of horn-cores whose structure is of considerable significance in a determination of the genetic relationships of the genus.

ACKNOWLEDGMENTS

In the comparative studies of the *Sphenophalos* remains, frequent reference has been made to the original specimens collected in the Thousand Creek beds of northwestern Nevada. The loan of this material has been kindly permitted by Professor W. D. Matthew of the University of California. Dr. Joseph Grinnell of the Museum of Vertebrate Zoology has likewise permitted the loan of skulls of the modern pronghorn for examination. The special study of the occurrence and relationships of *Sphenophalos* was supported by funds from Carnegie Institution of Washington, generously granted by Dr. J. C. Merriam. The illustrations are the work of Mr. John L. Ridgway.

OCCURRENCE AND DISTRIBUTION OF SPHENOPHALOS

Originally described by J. C. Merriam[1] from the Thousand Creek beds of northwestern Nevada, this genus was later recognized as occurring also in the Rattlesnake deposits of the John Day basin, north central Oregon. While both horizons have been referred to the Pliocene, it has been generally regarded that the Thousand Creek fauna is at least slightly later in stage of development than that represented by the Rattlesnake mammalian assemblage. Moreover, from the known information regarding related forms it has been assumed that the prevalent antelopine types of the early Pliocene and late Miocene are the merycodonts, while those of the Pleistocene are principally of the genera *Capromeryx* and *Antilocapra.* Thus the genus *Sphenophalos* has come to be regarded as particularly characteristic of the middle Pliocene, but apparently ranging somewhat farther back in this period.

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[1] J. C. Merriam, *The Occurrence of Strepsicerine Antelopes in the Tertiary of Northwestern Nevada,* Univ. Calif. Pub. Bull. Dept. Geol., vol. 5, No. 22, 319-330, Dec. 1909; *Tertiary Mammal Beds of Virgin Valley and Thousand Creek in Northwestern Nevada,* Univ. Calif. Pub. Bull. Dept. Geol., vol. 6, Part 1, No. 2, 21-53, 1920, vol. 6, Part 2, No. 11, 1911.

At the two new localities in eastern Oregon where *Sphenophalos* has been found, the associated types appear likewise to indicate a Pliocene age. Thus near Harper in northern Malheur County horn-cores of this genus were found in association with remains of rhinoceros (possibly *Teleoceras*), *Pliohippus,* a camel, proboscidean and canidæ. The mammalian assemblage was collected several miles northeast of Harper in loosely consolidated sands, gravels and ash overlying a thin sheet of basalt. The deposits appear to be stratigraphically distinct from a thick series of diatomite locally widespread and presumably of Miocene age.

The second occurrence in Malheur County was found along the Crooked Creek drainage, tributary to the Owyhee River, five miles southwest of Rome. The fauna from the later Tertiary beds in this region includes a rhinoceros, *Pliohippus,* peccary, camel, carnivora and mylagaulid rodents.

The fauna secured near Harper is at present perhaps too incompletely known to determine its relationship to the Thousand Creek and Rattlesnake mammalian assemblages. The fauna from the Pliocene deposits at Rome is sufficiently complete to permit, with more detailed study, a determination of its relationship to the known Pliocene assemblages of the Great Basin province.

DESCRIPTION OF MATERIAL FROM PLIOCENE DEPOSITS NEAR HARPER AND ROME, MALHEUR COUNTY, OREGON

The Harper specimens consist of a right and left horn-core. The right horn-core, No. 17 Calif. Inst. Coll., is more completely preserved than that (No. 16) of the left side. Specimen No. 16 (Plate I, figs. 1 to 4), comprising the anterior proximal portion and the horn-core, is practically complete to its distal extremity; the base is somewhat broken posteriorly immediately above the orbit. In No. 17 (Plate I, figs. 5 to 8) that portion of the base absent in No. 16 is present, but the anterior basal region is missing. However, the posterior tine is broken away just above the point of bifurcation.

The Owyhee specimen No. 395 (Plate 2, figs. 3, 4, 5) is a left horn-core that lacks the distal ends of the tines. A right horn-core specimen No. 396 (Plate 2, figs. 1, 2) lacks the anterior tine and part of the shaft. Specimen No. 399 (Plate 2, figs. 6, 7) is a frontlet that consists of the basal parts of the right and the left horn-cores and superior wall of the orbits.

The new specimens show characters not present in the materials from the University of California collection originally described by Merriam and further suggest a rather close relationship between *Sphenophalos* and *Antilocapra americana.* It is desirable to incorporate in Merriam's generic description the characters now seen in the more complete specimens.

BOVIDÆ

Sphenophalos nevadanus Merriam

GENERIC CHARACTERS

Based by Merriam on University of California Specimens

"Frontals not cavernous at the base of the horns. Horns situated on the upper posterior region of the orbits, sloping backward, slightly outward, and tilted upward at an angle between 25° and 30° from the plane of the frontals above the orbits. A short distance above the base, the horn-cores flare or widen slightly in the direction of greatest diameter in cross-section. Outer anterior edge of the horn-core arising over the upper posterior region of the orbit and swinging backward with a suggestion of a twist. Surface of the horn-core comparatively smooth, with a few pits or irregularities. Texture of the outer portion of the horn-core solid. Supraorbital foramina present in front of the middle of the antero-medial side of the base of the horn-cores."

Characters Based on Specimens of California Institute of Technology

Nos. 16, 17, 395, 396, 399

Position of supraorbital foramen as in *A. americana.* Longitudinal axis of horn-core in relation to basicranial axis as in *A. americana* skull. Position of horn-core above orbit at an angle oblique to the sagittal axis of skull. Distal anterior half of horn flares outward. Anterior margin of horn above anteroposterior expansion produced in a postero-concave line to a distal anterior prong. Horn-core bifurcate with low, anterior blunt prong and higher posterior prong. Bifurcation in the form of an anteroposterior elongate saddle. Distal half of horn-core surface with pitted texture as in *A. americana.*

DISCUSSION OF MORPHOLOGY

In specimen No. 17 (Plate 1, fig. 5) the anterior part of the roof of the orbit is present and shows a portion of the supraorbital foramen. The area of supraorbital rim that remains is slightly abraded.

The longitudinal axis of the horn-core centers above the middle of the orbit and is at right angles to the orbit. The horn-core held in position to conform with the position of the horn-cores in *A. americana* (Univ. Calif. specimen No. 8298) shows that its attitude in relation to the basicranial axis of *A. americana* is approximately the same.

In specimen No. 16 the postero-proximal part of the horn-core is present just above the orbit (Plate 1, fig. 1) with a small part of the roof of the orbit present. This region of the orbit in conjunction with that seen in specimen No. 17 (Plate 1, figs. 6, 7) confirms the view that the horn-cores in *Sphenophalos* have an attitude in relation to the skull like that in *A. americana.*

The apparent twisting observed in the fragmental parts of the Thousand Creek specimens, Univ. Calif. Coll. Nos. 11887-11888-22427 (Plate 5, fig. 4 and Plate 4, figs. 1, 2, 3), is due to the flaring outward of the anterior distal third of the horn-core.

Specimen No. 17 (Plate 1, fig. 7), viewed anteriorly, shows that portion of the horn-core above the proximal expansion and extending to the anterior prong to be flared outward. The flare occurs in advance of the median longitudinal axis of the horn-core and throws the front prong *en echelon* to the rear prong.

In both specimens, Nos. 16 and 17 (Plate 1, figs. 4 and 8), the posterior surfaces of the horns rise rather abruptly above the cranium and are broad transversely and but slightly rounded near the base. Toward the upper half the cores broaden transversely before converging to the tip of the posterior prong.

Both the median and lateral faces of the horn-core No. 17 (Plate 1, figs. 1 to 6) present a peculiar topography. The surface is pitted, like in *A. americana,* particularly along the anterior margin and over the distal third, including the prongs. The outer surface in specimen No. 17 (Plate 1, fig. 6) is sculptured by two broad, shallow depressions.

University of California specimen No. 22427 (Plate 4, fig. 2) has a shallow pit above the posterior margin of the supraorbital rim from which a relatively deep sulcus extends distally. The pit occurs in advance of a point where the temporal ridge becomes confluent with the base of the horn-core. A similar nutrient canal is present in specimen No. 17 (Plate 1, fig. 6). The temporal ridge and shallow pit have been broken away, but what remains of the canal can be interpreted as having the same basal characters as occur in the University of California specimen No. 22427.

In specimen No. 22427 (Plate 4, figs. 2, 3) a part of the wall of the cranial vault and the dorsal curvature of the junction of this part of the frontal with the base of the horn-core is present. This dorsal curvature is also present in specimen No. 16 (Plate 1, figs. 1, 2), though only a small part of the frontal remains at the posterior base of the horn-core. This region is like the corresponding part in specimen No. 22427. The presence in these specimens of the part of frontal bone just anterior to, and in places apparently broken along, the fronto-parietal suture line gives information which tends to confirm the belief that the attitude of the horn in *Sphenophalos* is not unlike that in *A. americana.*

The two specimens, Nos. 395 and 396 (Plate 2, figs. 1 to 5) from the Owyhee region, Oregon, conform very closely in character to those described above. They differ, however, somewhat in proportion and are relatively shorter. Both the lateral and median surfaces are more uniformly pitted, a character that may point to youth in the individuals. A further study and accession of more complete material from the Owyhee localities may demonstrate the presence of specific characters in these smaller forms other than those recognized in *S. nevadanus.*

The frontlet, specimen No. 399 (Pl. 2, figs. 6, 7), shows in the basal parts of the right and left horn-cores, and in the region of the orbit characters comparable to those exhibited in specimens described by Merriam from Thousand Creek, Nevada, and in the fragmentary horn-core (Univ. Calif. No. 22428) figured and described by Merriam and Stock.[1]

In 1928 Merriam and Stock[2] described and figured a peculiar horn-core, Univ. Calif. specimen No. 22430, from the Thousand Creek Pliocene beds. The horn-core has every appearance of being that of a young fawn. The specimen is perfectly formed for an immature individual and forecasts in the position of the distal prongs the position attained by growth in the adult animals. The apparent twist foreshadows the ultimate arrangement of the adult prongs and is probably not to be correlated with the spiral twist in the antilocaprid *Ilingoceros*.

The *Ilingoceros schizoceras* specimen figured by Merriam[3] exhibits characters that may lead to the hypothesis that *Ilingoceros* and *Sphenophalos* were derived from a common ancestor not very far removed in geological time.

Relations of Sphenophalos nevadanus to Quaternary Representatives of Antilocapra

Sphenophalos nevadanus Merriam, Univ. Calif. No. 22431 (Plate 5, fig. 2) from Thousand Creek, Nevada, is a frontlet that consists of the basal parts of the right and left horn-cores; also that portion of the frontal bone between the horns and extending to the fronto-parietal suture. Anteriorly it extends to the fronto-lachrymal suture. The supraorbital foramina are present.

A recent skull of *A. americana* collected in Virgin Valley, Nevada, Univ. Calif. M. V. Z. specimen No. 8298 (Plate 5, fig. 1) when studied with *Sphenophalos,* specimen 22431, is seen to resemble in a number of characters the Pliocene genus. The surfaces of *Sphenophalos* specimen 22431 are somewhat abraded by weathering. However, a cross-section through the stumps of the horns (Plate 5, fig. 2) gives one similar to that in *Antilocapra americana.* The horns in specimen 22431 occupy, as in *A. americana,* a position above the supraorbital rim and their position in relation to the longitudinal and to the basicranial axes of the skull is similar. From the apex of the frontal bone between the horns, the plane of the cranial roof posteriorly and anteriorly indicates a basicranial axis like that in the pronghorn antelope. The frontals are depressed forward between the supraorbital foramina to the dorsal margin of the cribriform plate, as in *A. americana.* The supraorbital foramina in *A. americana* are sometimes double as in specimen No. 8298 or may be single as in Calif. Inst. Tech. specimen *A.* cf. *americana* No. 46 (Plate 5, fig. 3). In *S. nevadanus,* Univ. Calif. specimen No. 22431, they are single; the right foramen, however, shows an incipient division.

The outer margin of the supraorbital rim in No. 22431 is broken away, but a sufficient portion of the roof of the orbit is present to show that its contour is like that in *A. americana* (speicmen No. 8298) and in *A.* cf.

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[1] J. C. Merriam, C. Stock and C. L. Moody, ***The Pliocene Rattlesnake Formation and Fauna of Eastern Oregon with Notes on the Geology of the Rattlesnake and Mascall Deposits,*** Contrib. to Palæontology, Carnegie Inst. Wash. Pub. No. 347, 1925.

[2] J. C. Merriam and C. Stock, ***A Further Contribution to the Mammalian Fauna of the Thousand Creek Pliocene, Northwestern Nevada,*** Carnegie Inst. Wash. Pub. No. 393, 1928.

[3] J. C. Merriam, Univ. Calif. Pub. Bull. Dept. Geol., vol. 6, 293, figs. *73a, 73b.*

americana (Calif. Inst. Tech. specimen No. 46) from McKittrick. The small depression, sometimes a deep pit, just back of the orbit at the outer base of the horn-core near the fronto-parietal suture, found in *A. americana,* is present also in *S. nevadanus,* specimens Nos. 22427 and 22431. The individual, No. 22431, though only the base of the horns is present, affords an approximately correct position and attitude of the horn-cores in relation to the axis of the skull of *Sphenophalos.* Like in *A. americana,* the horns of *S. nevadanus* are broad posteriorly and narrow uniformly to the relatively sharp, anterior margin (Plate 5, figs. 1 to 4). The horns incline outward at an angle from the sagittal plane of the skull, so that the distal end, if it were present, would terminate laterally beyond and above the posterior border of the orbit.

The type specimen of *S. nevadensis,* Univ. Calif. No. 11887 from Thousand Creek, Nevada, figured by Merriam, closely approximates in size specimen No. 17 from Malheur County, Oregon. The superior rim of the orbit (Plate 4, fig. 8) is present, and like that in *A. americana* No. 8298 (Plate 4, fig. 7) is tubular and has a notch or depressed area at the apex of its dorso-ventral diameter. The eye socket is deep, the entire roof of the orbit being surmounted by the horn-core. The horn-core is broader transversely than in *A. americana* No. 8298 and in *S. nevadanus* specimen 17 from Oregon. The area lying between the postero-superior orbital rim and the anterior part of the temporal ridge is slightly depressed, but has no deep pit as in *A. americana* 8298, though it closely approximates the same region in a younger individual of *A. americana.* The temporal ridge is produced dorsally, anteriorly to the base of the horn. In *A. americana* it curves laterally around and below the base of the horn. The posterior base of the horn-core in *A. americana* and *A.* cf. *americana* Nos. 8298 and 209 is developed as a rather prominent boss just above the anterior margin of the temporal ridge, and the broad posterior base of the horn is oblique to the longitudinal plane of the skull.

A right horn-core of *A.* cf. *americana* (Plate 4, fig. 5) Calif. Inst. Tech., specimen No. 46, from the McKittrick Pleistocene beds, has all the parts under discussion. It is similar in many characters to *S. nevadanus,* Univ. Calif. No. 11888 (Plate 5, fig. 4), Thousand Creek beds. It is relatively broader at the base, posteriorly, than *A. americana* No. 8298 and is approximately as broad as in *S. nevadanus* No. 11888. The antero-posterior diameter just above the orbit is close to that in specimen No. 11888.

The horn-core of the Pleistocene pronghorn is slender as compared with the recent skull No. 8298, and the anterior appressed prong is more distally placed (Plate 4, fig. 5). The distal anterior projection in the specimens of *A. americana* and *A.* cf. *americana* can be considered as homologous with the anterior prong characteristic of *S. nevadanus.* The forward distal projection varies in longitudinal position on the shaft in the skulls of *A. americana* which have been examined.

The horn-core in *S. nevadanus* No. 17 is a heavier element than that in *A. americana* No. 8298—thicker in proportion to its height, which is less by approximately 20 mm. than specimen No. 8298.

The Rancho La Brea Pleistocene *A.* cf. *americana,* Los Angeles Museum specimen Z885, consists of the cranial part of the skull with a fairly complete left horn-core. The horn is somewhat broken anteriorly, the anterior superior part of the orbital rim being also absent.

In *S. nevadanus,* Univ. Calif. specimen No. 11887, a rather pronounced ridge extends from the postorbital region of the supraorbital rim posteriorly and distally to merge into the shaft of the horn. In *A.* cf. *americana,* specimen Z885, a ridge approximately like this in character is present. In the Pleistocene specimen it gives rise to a rather deep pit, more or less pronounced in the existing pronghorn antelopes. Likewise a deep sulcus in advance of the ridge which is present in this type is found to be absent in *S. nevadanus* and in specimens of *A. americana* examined.

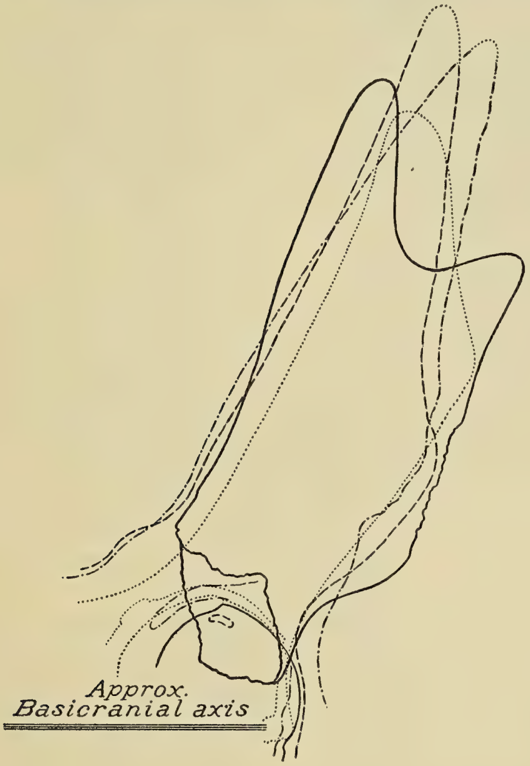

FIG. 1—Profile views of the right horn-core in Pliocene and Quaternary antelopes.

—— *Sphenophalos nevadanus* Merriam. Harper, Oregon, Pliocene.

– – – *Antilocapra* cf. *americana,* Rancho la Brea, California, Pleistocene.

–·– *Antilocapra americana,* Northwestern Nevada, Recent.

.... *Antilocapra* cf. *americana,* McKittrick, California, Pleistocene.

The boss at the posterior base of the horn in the recent skull 8298, before mentioned, is present in an appressed form in the Pleistocene specimen Z885 but is absent in some recent skulls and in the McKittrick Pleistocene horn-core No. 46.

In view of the present more complete information concerning the horn-core in *Spenophalos,* the fragmentary specimen from Thousand Creek which resembled *Neotragoceros*[1] and *Aploceros* may now be regarded as the terminal part of the posterior prong of *Sphenophalos.*

Merriam in discussing the systematic position of *Sphenophalos* recognized in the study of the incomplete horn-cores, then available, characters that indicate a close relationship to the pronghorn antelopes.

This relationship is rather strongly supported by the comparisons which are now possible on the basis of more complete material. When the profiles of the horn-cores of *Sphenophalos* and of Quaternary representatives of *Antilocapra* are super-imposed (fig. 1), the principal difference appears in the region of the anterior prong. The latter structure has evidently suffered a gradual reduction in size during the evolution of this stem of the antilocaprid group in later Cenozoic time.

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[1] W. D. Matthew and H. Cook, Bull. Amer. Mus. Nat. Hist., vol. 26, 413-414, 1909.

It is interesting to note that the sheath covering the horn-cores in skulls of the Recent pronghorn occasionally lacks the anterior prong and gradations in size of prong are also to be seen in the living animals.

While complete skulls of *Sphenophalos* are lacking and a definite association of teeth and horn-cores has not been established, antilocaprid teeth have been found in the immediate vicinity of horn-core specimens. It appears safe to assume that teeth occurring under such circumstances represent this Pliocene genus. These teeth are similar in size and in structure and pattern of crown to comparable teeth in *A. americana.* The crowns are long and possess open roots. In characters of the dentition *Sphenophalos* is more advanced than *Merycodus* from the Barstow Miocene and Ricardo Pliocene and *Capromeryx* from the Pleistocene.

CONCLUSIONS

The distribution of *Sphenophalos* as now known extends through the northern portion of the Great Basin Province. Additional remains have been collected at the type locality in the Thousand Creek beds of northwestern Nevada. This Pliocene genus is also recorded from two localities in southeastern Oregon. The presence of *Sphenophalos* in Tertiary beds near Harper and Rome in Malheur County, Oregon, furnishes evidence that the deposits are related in age to the Thousand Creek and Rattlesnake. The latter have been regarded as middle and lower Pliocene in age.

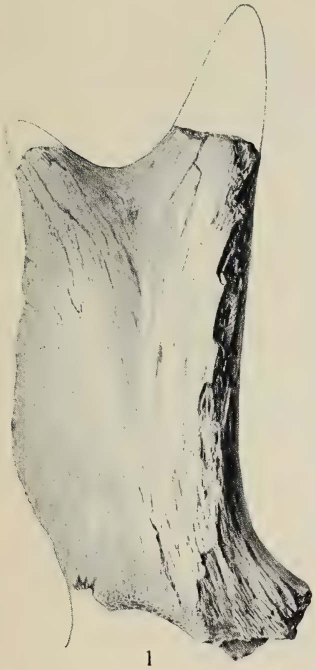
The morphologic characters displayed by the newly discovered skull material of *Sphenophalos* emphasize the close relationship between this genus and later Cenozoic antilocaprids. Evidence based primarily on the frontlet region and horn-cores strongly supports the view that *Sphenophalos* stands in direct ancestral relationship to *Antilocapra americana.* The region under discussion may well be in or near the center of origin of the modern pronghorn antelope.

Description of Plate 1

Sphenophalos nevadanus Merriam. California Institute of Technology specimens No. 16 and No. 17. Locality 42, vicinity of Harper, Malheur County, Oregon.

Figs. 1 to 4. Specimen No. 16 left horn-core, outer side, inner side, front and rear views respectively.

Figs. 5 to 8. Specimen No. 17 right horn-core, views correspond to those in specimen No. 16.



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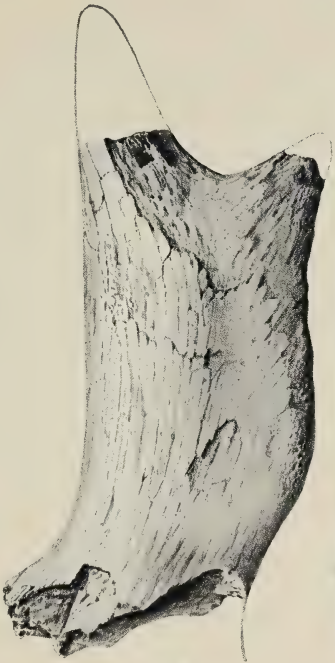

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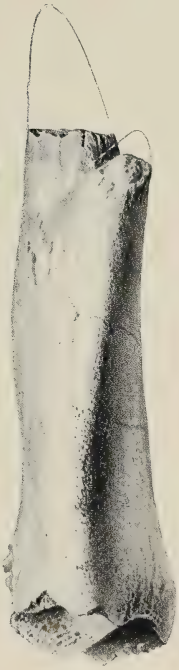

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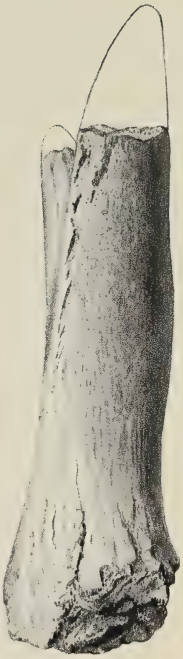

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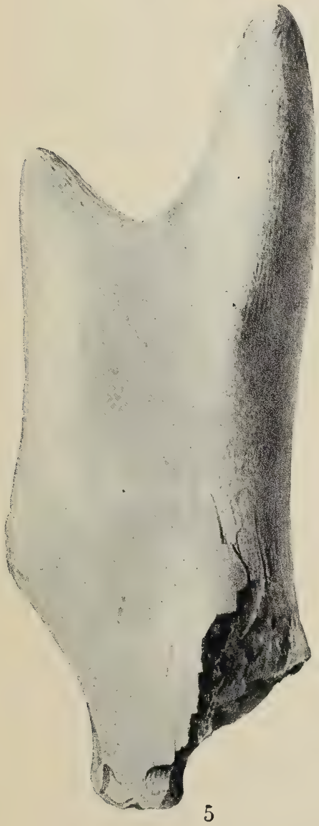

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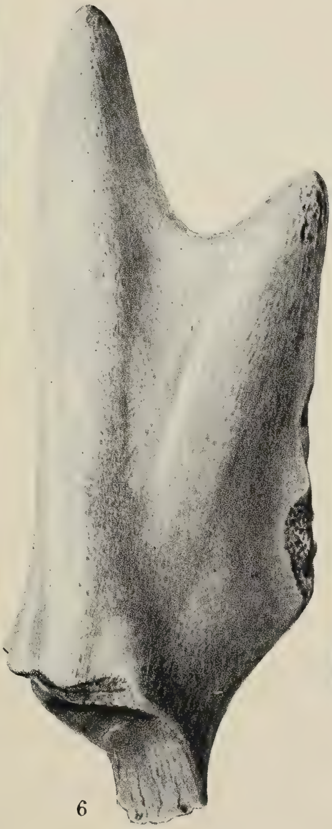

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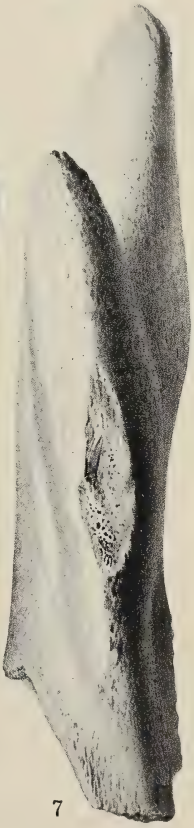

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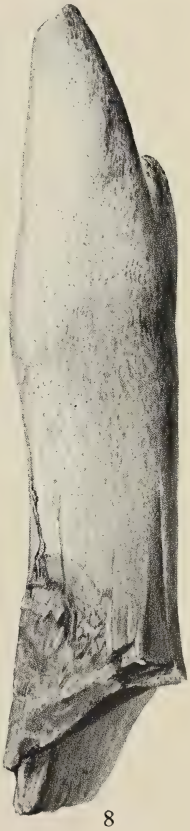

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Reproductions two-thirds natural size

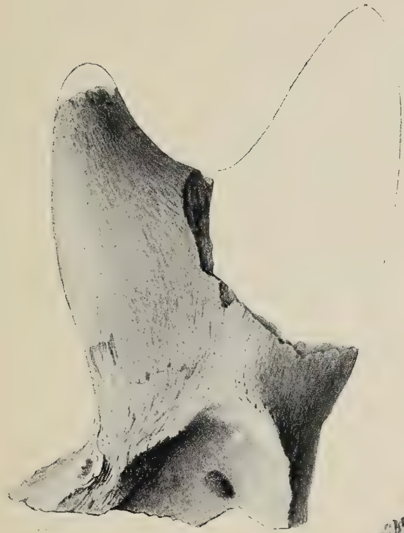
DESCRIPTION OF PLATE 2

Sphenophalos nevadanus Merriam. California Institute of Technology specimens from vicinity of Rome, Oregon.

FIGS. 1 and 2. Outer side and inner side views of right horn-core. Probably young adult individual.

FIGS. 3, 4, 5. Inner side, front, and outer side views of right horn-core. Probably young adult individual.

FIGS. 6 and 7. Anterior and posterior views of frontlet of mature adult.



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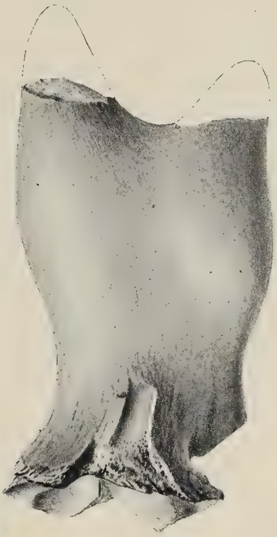

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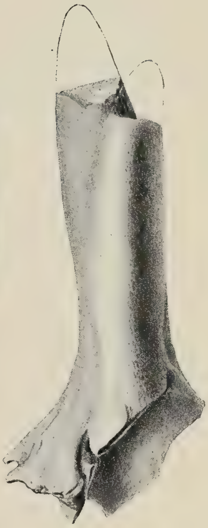

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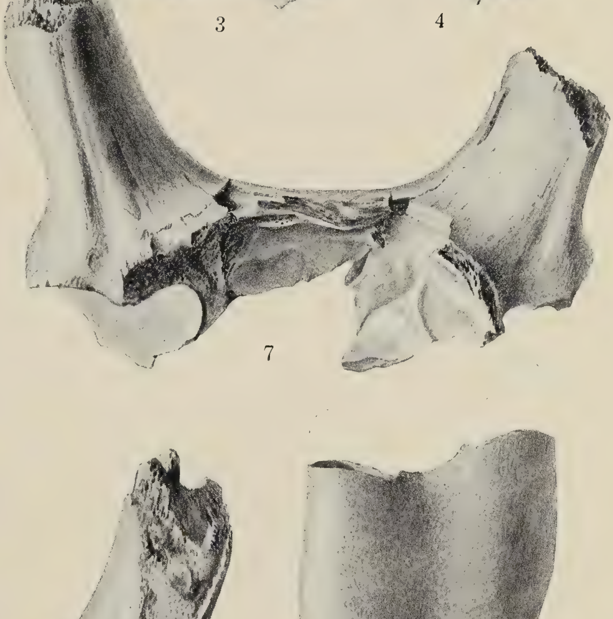

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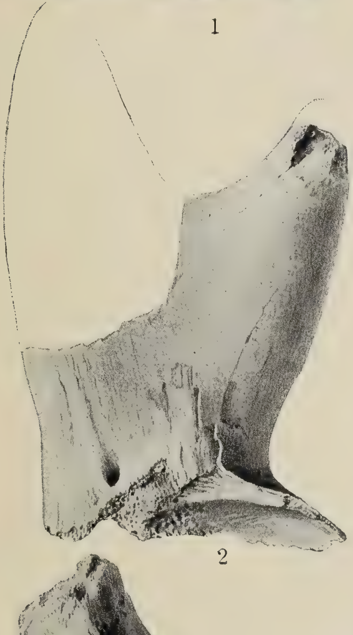

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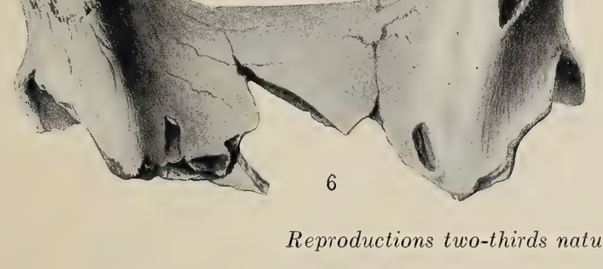

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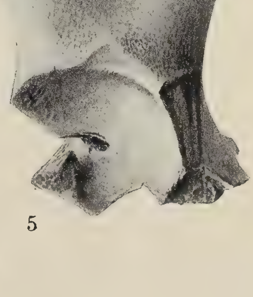

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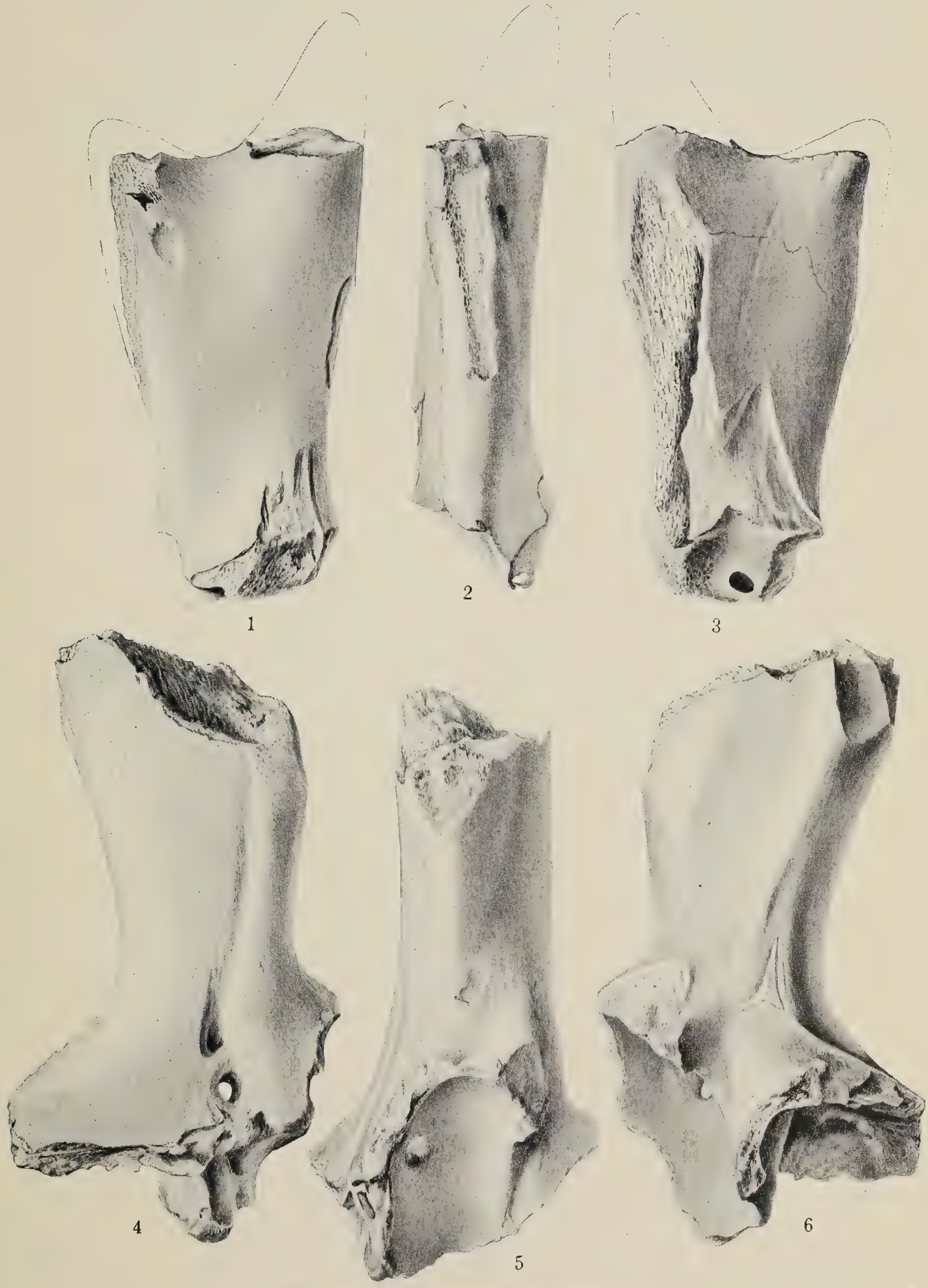
Description of Plate 3

Sphenophalos nevadanus Merriam. California Institute of Technology specimens from Thousand Creek, Nevada.

Figs. 1, 2, 3. Inner side, front and outer side views of right horn-core. Mature individual.

Figs. 4, 5, 6. Same views as above of left horn-core of larger adult.



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Description of Plate 4

Figs. 1, 2, 3, 4. *Sphenophalos nevadanus* Merriam. University of California specimen 22427 from Thousand Creek locality.

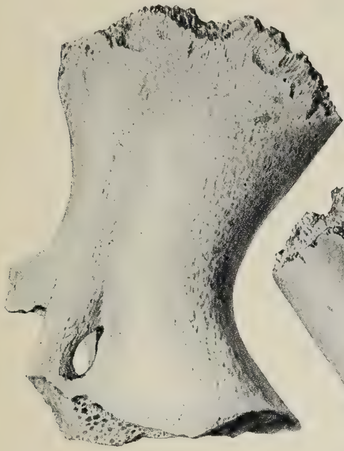
Fig. 1, inner side and basal part of right horn-core; fig. 2, outer side showing part of supraorbital rim; fig. 3, front view showing part of supraorbital rim; fig. 4, rear view showing curvature from frontal bone near base of horn-core.

Fig. 5. *Antilocapra* cf. *americana.* California Institute of Technology specimen 46 from McKittrick Pleistocene, California, inner side view of horn-core.

Fig. 6. *Sphenophalos nevadanus* Merriam. University of California specimen 11888 from Thousand Creek, Nevada, inner side view of horn-core. For posterior view see plate 5, figure 4.

Fig. 7. *Antilocapra americana.* University of California Museum of Vertebrate Zoology specimen 8298 from Northwestern Nevada. View of orbit showing orbital rim and notch in supraorbital part.

Fig. 8. *Sphenophalos nevadanus* Merriam. University of California specimen 11887 from Thousand Creek beds, Nevada. View showing supraorbital part of rim and median notch near base of horn-core.



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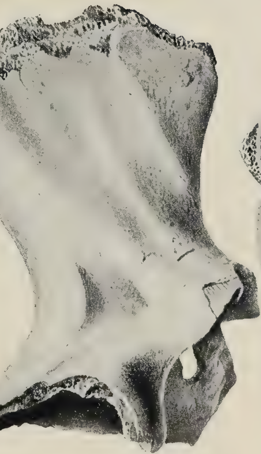

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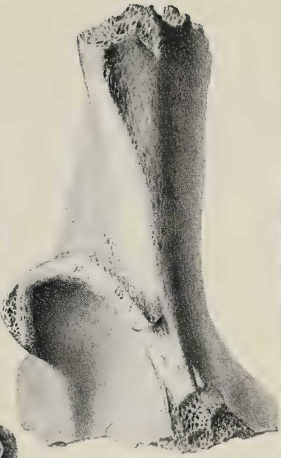

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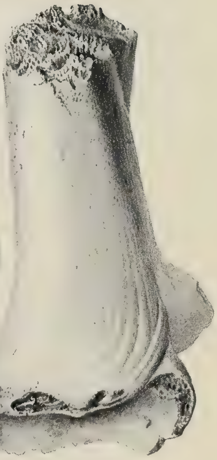

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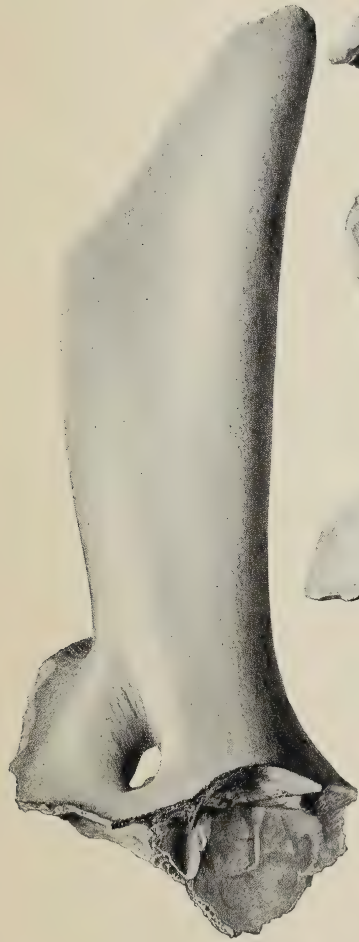

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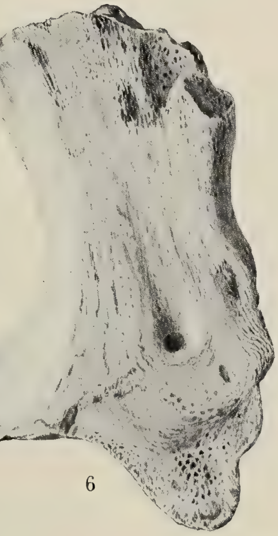

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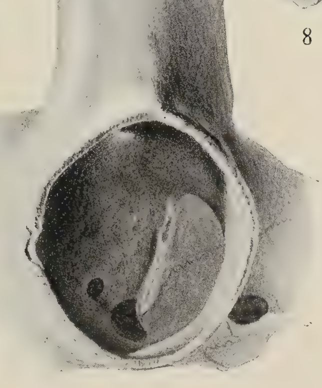

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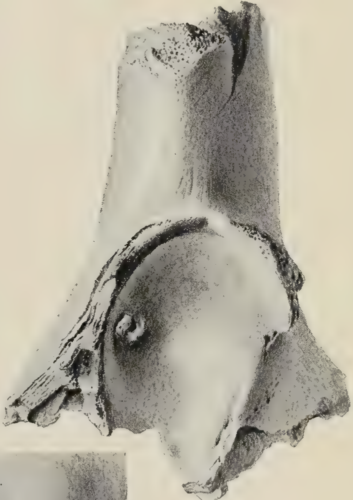

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Reproductions two-thirds natural size

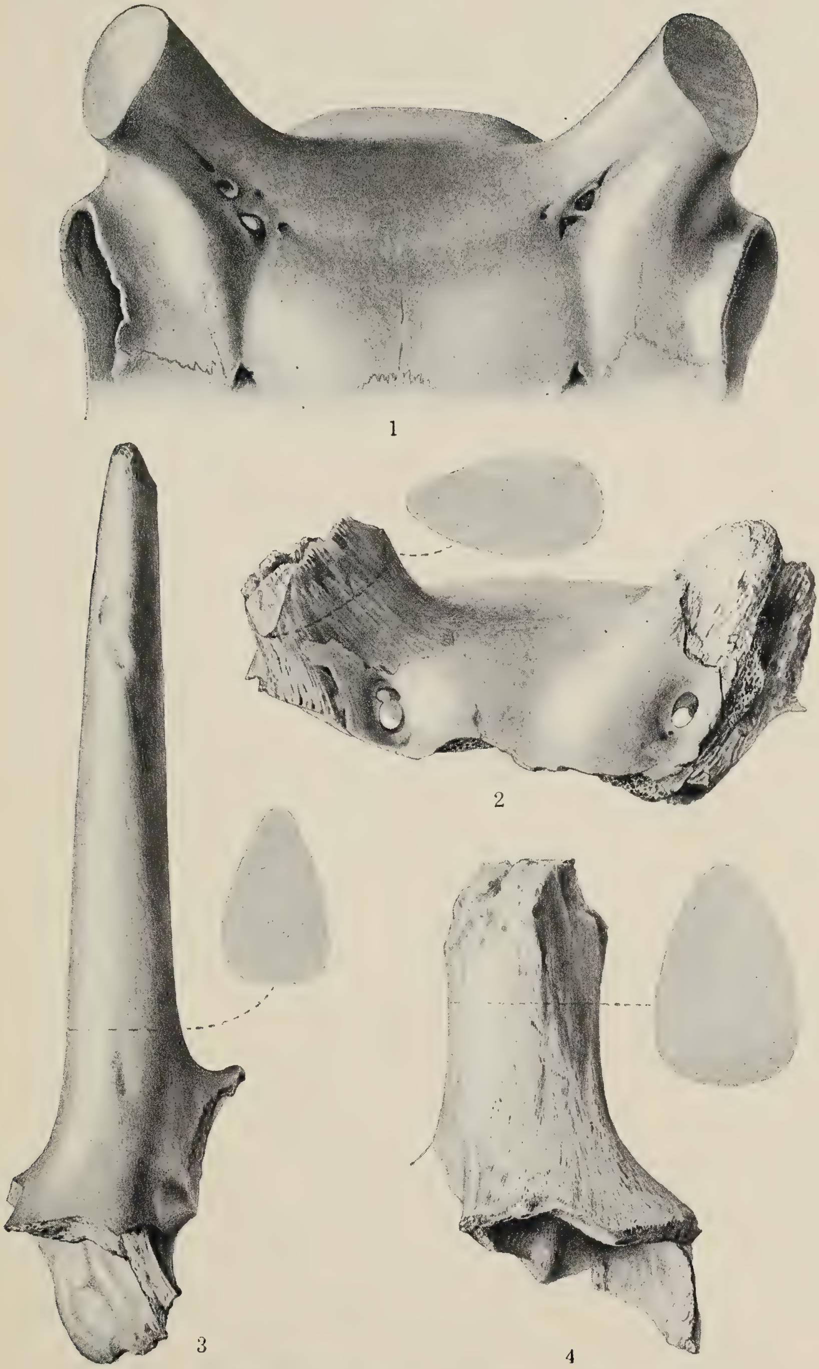
Description of Plate 5

Fig. 1. *Antilocapra americana.* University of California Museum of Vertebrate Zoology specimen 8298 from Northwestern Nevada. Anterior view of the frontlet region of the cranium showing attitude of horn-cores in position normal to basicranial axis of skull. Also shows cross-section through horn-cores.

Fig. 2. *Sphenophalos nevadanus* Merriam. University of California Palæontological Collection, specimen 22431 from Thousand Creek Beds, Nevada. Anterior view of frontlet in position comparable to that shown in figure 1. Position of horn-cores and section through right horn-core shown.

Fig. 3. *Antilocapra* cf. *americana.* California Institute of Technology, specimen 46 from McKittrick Pleistocene, California. Posterior view showing attitude of right horn-core above frontal bone with section through horn-core.

Fig. 4. *Sphenophalos nevadanus* Merriam. University of California specimen 11888 from Thousand Creek beds, Nevada. Posterior view of horn-core showing characters illustrated in figure 3.



Reproductions two-thirds natural size

III

A MIOCENE MAMMALIAN FAUNA FROM SOUTHEASTERN OREGON

By C. Lewis Gazin

With six plates and twenty text-figures

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A MIOCENE MAMMALIAN FAUNA FROM SOUTH-EASTERN OREGON

INTRODUCTION

In the course of paleontological explorations in southeastern Oregon during the summer field seasons of 1928 and 1929 California Institute parties have been fortunate in securing collections of mammalian remains in Tertiary deposits exposed in the northern portion of Malheur County. Attention was first directed to the so-called Skull Spring occurrence by Mr. C. J. Bush of Harper, Oregon.

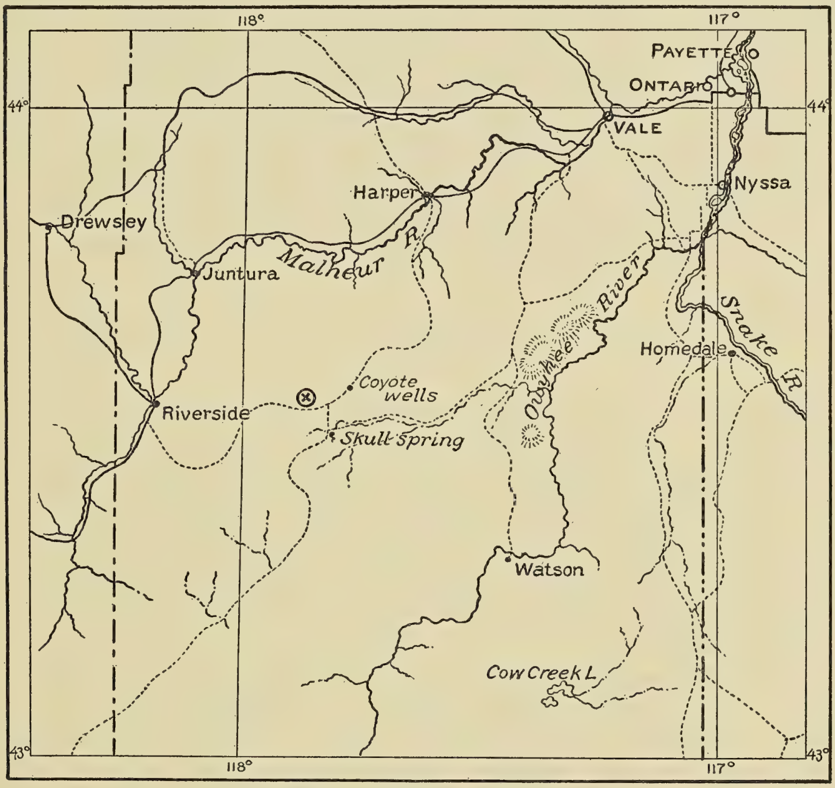

FIG. 1—Index map of a portion of eastern Oregon and adjacent region of western Idaho, showing location ⊗ of Skull Spring fossil vertebrate occurrence.

The fossil locality is twenty-eight miles south of Harper, Malheur County, Oregon, and approximately three miles northwest of Skull Spring. The beds in which the mammalian remains were found occur in a small basin draining southward and eastward into the Owyhee River. The local drainage is a part of a tributary known as Dry Creek or Beaver Creek. The northern margin of the basin is situated on the divide between the Owyhee and Malheur systems. Beyond this divide the gradient is northward through Red Ridge basin and Cottonwood Creek to the Malheur River at Harper flats.

Field operations were conducted with the cooperation of the Carnegie Institution of Washington and were under the direction of Dr. Chester Stock of the California Institute of Technology. The author is indebted to Dr. Stock for the opportunity to study the fauna and for valuable advice and criticism during the progress of the investigation.

The author was associated in the field with Dr. Chester Stock, E. L. Furlong and L. C. Hookway during the first season; and with E. L. Furlong, F. D. Bode, S. W. Lohman and E. R. Inglee during the second summer. Acknowledgment is also made of the courtesy extended by Mr. Donald R. Dickey and staff at the California Institute of Technology in permitting unreserved use of the Dickey collection of Recent mammals. The drawings for the text-figures were made by Mr. John L. Ridgway. The photographs reproduced in the plates have been carefully and accurately retouched by Mr. Ridgway.

PREVIOUS STUDIES IN EASTERN OREGON AND ADJACENT REGIONS

The small basin from which the mammalian fauna has been secured appears to be one of several basins of Tertiary sediments occurring in eastern and southeastern Oregon and in the adjacent region of Idaho. The earlier studies relating to the geologic history of this area include those of Clarence King, E. D. Cope, I. C. Russell, Waldemar Lindgren and F. H. Knowlton. More recent investigations have been conducted by J. C. Merriam, R. W. Chaney, J. P. Buwalda and Kirk Bryan.

A survey of previous paleontological explorations in southeastern Oregon and adjacent regions indicates no special dearth of fossil material. The collections thus far obtained quite clearly indicate the presence of several stages in the Neocene life-record, of which those of the Idaho and Payette formations may be regarded as fairly well established. Determination of age of these deposits and an interpretation of the geologic history have come to rest largely on evidence presented by paleobotany and vertebrate paleontology.

The paleobotanical materials studied by Knowlton[1] and by Chaney[2] are apparently recorded exclusively from the Payette.

Vertebrate remains have been identified or described from the Idaho and Payette beds by Cope, Leidy, Marsh, Lucas, Merriam and

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[1] F. H. Knowlton, 18th Ann. Report, U. S. Geol. Surv., Pt. 3, pp. 721-744, 1898.

[2] R. W. Chaney, Amer. Jour. Sci., ser. 5, vol. 9, pp. 214-222, 1922.

Buwalda. A description of the fossil fish from the Idaho formation by Cope[1] in 1883 is perhaps the earliest report concerned with the vertebrate paleontology of this region. In 1898 Lindgren[2] recorded a determination by Leidy of *Mastodon mirificus* and *Equus excelsus* from the Idaho beds and a statement from Marsh that many Pliocene mammalian fossils occur in the bluffs along the Snake River below Weiser. In later collections made in the Idaho beds for Lindgren,[3] F. A. Lucas identified *Mastodon, Castor, Equus, Rhinoceros, Procamelus, Cervus* and an antelope. An equid type in the collection was recognized by Marsh as *Protohippus.* A collection made by Russell[4] included a camel, an edentate and fish remains, which Lucas considered to be of Pliocene age.

Later, in 1917, Merriam[5] discussed the relationship of the Idaho vertebrate fauna to other Pliocene assemblages, and in 1918[6] described three new species from these beds, *Ischyrosmilus idahoensis, Neotragocerus lindgreni* and *Equus idahoensis.* In 1924 Buwalda[7] recognized the occurrence of Miocene and Lower Pliocene forms in the Payette beds of Idaho. The earlier fauna included a mastodont, *Hypohippus, Merycodus,* camel, rhinoceros, fish and freshwater shells. The material from the later horizon consisted chiefly of *Hipparion* and rodent teeth. The lower Pliocene fauna may correspond to that recognized at Ironside, Malheur County, Oregon, by Merriam[8] in 1916.

RESUMÉ OF GEOLOGIC RELATIONS OF TERTIARY FORMATIONS IN NORTHEASTERN MALHEUR COUNTY, OREGON

The sequence of Tertiary rocks exposed in the region of the Skull Spring fossil occurrence includes the following: (1) a coarse tuff,[9] (2) the Owyhee basalt,[10] (3) the Payette formation, (4) the Idaho formation and (5) capping lavas. Local flows of rhyolite occur at several horizons in the stratigraphic succession. The oldest rhyolite[11] observed occurs between the Owyhee basalt and the underlying tuff. A later extrusion in the vicinity of Skull Spring apparently overlies the basalt series but does not intrude the lake beds. A third period of acidic lava which intrudes the Payette beds is recognized in the vicinity of Succor Creek, Oregon.

[1] E. D. Cope, Proc. Acad. Nat. Sci. Phila., pp. 134-166, 1883.

[2] W. Lindgren, 18th Ann. Rpt. U. S. Geol. Surv., Pt. 3, p. 628, 1898.

[3] W. Lindgren, 20th Ann. Rpt., U. S. Geol. Surv., Pt. 3, p. 99, 1900.

[4] I. C. Russell, U. S. Geol. Surv. Bull. 199, p. 56, 1902.

[5] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, pp. 431-434, 443, 1917.

[6] J. C. Merriam, *Ibid.,* vol. 10, pp. 523-530, 1918.

[7] J. P. Buwalda, Science, n.s., vol. 60, pp. 572-573, 1924.

[8] J. C. Merriam, *Ibid.,* vol. 10, pp. 129-135, 1916.

[9] Exposed in the "Hole in the Ground" along the lower part of the Owyhee River. Blue-green tuff resembling John Day and underlying the basalt in the Steens Mountains west of the Alvord Ranch may be broadly equivalent.

[10] See Kirk Bryan, U. S. Geol. Surv. Water Supply Paper 597-A, pp. 1-72, 1929.

[11] The rhyolite in part at the Owyhee damsite.

The beds at the Skull Spring fossil locality consist principally of ash and lie on the irregular surface of the rhyolite, which in turn appears to overlie the Owyhee basalt. These beds form an isolated occurrence which may have been connected at some earlier time with strata in the basin immediately to the north. The latter beds are apparently traceable between the underlying rhyolite and basic rim-rock to the section exposed in the vicinity of Harper flats. If a stratigraphic correlation can be definitely established, as appears quite likely, the fauna secured at the Skull Spring locality would presumably be closely related in time to that of the Payette.

OCCURRENCE AND PRESERVATION OF MATERIAL

The relief in the basin where the fossil materials were found is very low and the exposures are limited in extent. Much of the surface is covered with a growth of sagebrush and is strewn with lava detritus. Many specimens were collected in small dry stream beds along the bases of the more pronounced ridges. Some of the material was residual on the surface of the slopes and other specimens were located in place. No complete skeletons were found. Most of the scattered remains were preserved in nodules which were often so worn as to expose parts of bones or teeth. A large number of nodules not exhibiting organic remains at the surface were broken open and in some instances small rodent skulls were discovered. The nodules were frequently found mingled with rhyolite pebbles in the sandy drainage courses.

SKULL SPRING FAUNA[1]

The following is a list of the forms recognized in the assemblage:

- Carnivora
    - Canidæ
        - Tomarctus, cf. brevirostris Cope
        - Euoplocyon ? sp.
        - Canid ? sp.
        - Amphicyon sinapius Matthew
        - Amphicyon cf. frendens Matthew
        - cf. Pliocyon medius Matthew
        - Hemicyon n. sp.
    - Mustelidæ
        - Mustelid n. sp.

- Rodentia
    - Sciuridæ
        - Sciurus malheurensis n. sp.
        - Sciurus tephrus n. sp.
        - Citellus ridgwayi n. sp.
    - Aplodontiidæ
        - Liodontia alexandræ (Furlong)
    - Mylagaulidæ
        - Mylagaulus, cf. lævis Matthew
    - Heteromyidæ
        - Diprionomys ? oregonensis n. sp.

- Perissodactyla
    - Equidæ
        - Hypohippus sp.
        - Parahippus, near coloradensis Gidley
        - Merychippus isonesus (Cope)
    - Rhinocerotidæ
        - Rhinocerotid sp.
    - Chalicotheriidæ ?
        - Chalicothere ? sp.

- Artiodactyla
    - Tayassuidæ
        - Platygonus ? sp.
    - Agriochoeridæ
        - Ticholeptus ? sp.
    - Cervidæ
        - Dromomeryx, near borealis (Cope)
        - Blastomeryx ? sp.
    - Merycodontidæ
        - Merycodus ? sp. a
        - Merycodus ? sp. b

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[1] Material recently secured from a second Skull Spring locality includes mastodon and tapir in addition to many of the forms listed here.

ENVIRONMENT OF FAUNA

Suggestions as to the environmental conditions which prevailed during the period of accumulation of the deposits containing the Skull Spring fauna are presented by the mammalian types occurring in this assemblage. Moreover if the Skull Spring horizon is the direct correlative of the Payette in the region immediately adjacent, further evidence may be reasonably expected from a consideration of the Payette flora.

The Skull Spring fauna is apparently not a plains assemblage in which would usually occur grazing horses, camels, antelopes, rabbits and doubtless other forms. Rather does it suggest a semihumid or perhaps forest environment. Among the perissodactyla occur brachydont horses, particularly *Hypohippus.* Associated with these forms are rhinoceroses and chalicotheres.

Perhaps the most diagnostic types are the rodents, among which are recorded the tree and ground squirrels, and in particular the genus *Liodontia,* a form related to the so-called mountain beaver. It is interesting to note that the Recent *Aplodontia* requires a considerable degree of humidity and an abundance of food plants[1] and is limited in its range to the coastal region of southern British Columbia, Washington, Oregon and northern California. Possibly the genus *Mylagaulus* was characterized by a somewhat similar habitat.

The ecologic significance of the pocket mouse in the Skull Spring fauna is uncertain as Recent genera of this group are not all found living under similar climatic conditions. The present range of heteromyids extends from the humid tropics of Central America to the arid and even cold parts of the Sonoran region. The absence of Lagomorphs in so large an assemblage of rodent material is peculiar and may be of significance, since these forms though present in wooded areas are more commonly found on the plains.

Substantiating evidence is presented by the Payette flora. According to R. W. Chaney[2] the scarcity of sequoia in the Payette suggests a lower humidity than that for the Mascall, but the plant assemblage as a whole indicates greater relief. A dry upland slope with several kinds of oak and other plants and swampy stream or lake borders are suggested. The climatic conditions indicated by the flora are compared with those of northern California and southwestern Oregon. The environment described compares favorably with that required for the habitat of *Aplodontia,* and is probably that in which *Liodontia* lived.

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[1] W. P. Taylor, Univ. Calif. Publ., Bull. Dept. Zool., vol. 17, p. 450, 1918.

[2] R. W. Chaney, Amer. Jour. Sci., ser. 5, vol. 9, pp. 214-222, 1922.

STAGE OF EVOLUTION OF FAUNA

The different elements of the mammalian fauna indicate rather uniformly the same time stage in their phylogenetic history. On the basis of the present age-determinations of Tertiary faunal horizons of western North America, the Skull Spring assemblage may be regarded as middle Miocene in age or perhaps slightly later. The canids are those typically occurring in comparable Miocene horizons of the Great Plains region. The genus *Hemicyon* may be an exception. This form exhibits characters which may be reasonably expected at this faunal stage, but the genus is practically unknown elsewhere in America in horizons earlier than the Barstow and Santa Fé. The rodents as a group indicate a Neocene age. The Equidæ include the most diagnostic types and an age-determination of the fauna is based principally on members of this family. *Merychippus isonesus,* for example, occurs at Skull Spring and in the Mascall and Virgin Valley faunas. Unfortunately the artiodactyls are known by very incomplete materials and in most instances their relationships can not be definitely established. *Ticholeptus* has been regarded as characteristic of the middle Miocene, but the occurrence of the genus at the Oregon locality is questioned. Characters displayed by *Platygonus* (?) and *Merycodus* (?) sp. *b* appear to be rather advanced for types occurring in this stage.

RELATIONSHIPS OF FAUNA

The Tertiary horizons most closely related to the Skull Spring stage in time and in geographic propinquity are the Mascall formation of east-central Oregon and the Virgin Valley beds of northwestern Nevada. These deposits may represent with the beds in the vicinity of Skull Spring a nearly contemporaneous accumulation during a period of relatively low relief, following the extrusion of an extensive basalt series.

Merychippus isonesus (Cope) [1] was originally described from the Mascall,[2] and a number of associated forms are common to the two localities. However, the ungulate fauna resembles more closely in its association of types that found in the Virgin Valley beds.[3] A comparison of the three faunal lists is given below.

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[1] E. D. Cope, Proc. Amer. Philos. Soc., vol. 26, pp. 451-457, 1889.

[2] See J. C. Merriam and W. J. Sinclair, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 195-197, 1907.

[3] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, pp. 204-209, 1911.

Skull Spring	Virgin Valley	Mascall
		Percomorphi
		Plioplarctus septemspinosus Cope
	Testudinata	Testudinata
	Clemmys sp.	Clemmys saxea Hay
Carnivora	Carnivora	Carnivora
Tomarctus, cf. brevirostris Cope	Tephrocyon kelloggi Merriam	Tephrocyon rurestris (Condon)
	Tephrocyon, compare rurestris (Condon)	
	Tephrocyon sp. a	
	Aelurodon ? sp.	
Euoplocyon ? sp.		
Canid ? sp.		Canis ? sp.
Amphicyon sinapius Matthew		Amphicyon sinapius Matthew
Amphicyon, cf. frendens Matthew		
cf. Pliocyon medius Matthew		
Hemicyon n. sp.		
Mustelid n. sp.		Lutrictis lycopotamicus Cope
		Leptarctus oregonensis Stock
	Bassariscus antiquus matthewi Merriam	
	Felis sp. a ?	
Rodentia	Rodentia	Rodentia
Sciurus malheurensis n. sp.		
Sciurus tephrus n. sp.		
Citellus ridgwayi n. sp.		
Liodontia alexandræ (Furlong)	Liodontia alexandræ (Furlong)	
Mylagaulus, cf. lævis Matthew	Mylagaulus monodon Cope	
	Mylagaulus pristinus Douglass	Mylagaulus sp.
Diprionomys ? oregonensis n. sp.		Diprionomys sp.[1]
		Chalicomys sp.
		Peromyscus (?) sp.
	Lagomorpha	Lagomorpha
	Oreolagus nevadensis (Kellogg)	
	Hypolagus vetus (Kellogg)	Lepus ? sp.

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[1] An undescribed specimen in a collection recently obtained from the Mascall.

SKULL SPRING	VIRGIN VALLEY	MASCALL
	Proboscidea	Proboscidea
	Mastodont sp.	Mastodont sp.
Perissodactyla	Perissodactyla	Perissodactyla
Hypohippus sp.	Hypohippus, near osborni Gidley	
		Archæohippus ultimus (Cope)
		Archæohippus sp. indesc.
Parahippus, near coloradensis Gidley	Parahippus, compare avus (Marsh)	Parahippus avus (Marsh)
		Parahippus brevidens (Marsh)
Merychippus isonesus (Cope)	Merychippus isonesus (Cope)	Merychippus isonesus (Cope)
		Merychippus seversus (Cope)
		Merychippus relictus (Cope)
		Merychippus insignis Leidy
Rhinocerotid sp.	Aphelops ? sp.	Diceratherium oregonense (Marsh)
		Rhinocerotid sp. & gen. indet.
Chalicothere ? sp.	Moropus merriami Holland and Peterson	
Artiodactyla	Artiodactyla	Artiodactyla
	Perchœrus ? sp.	
Platygonus ? sp.		
Ticholeptus ? sp.		
	Merychyus ? sp.	
		Merycochœrus sp.
		Merycoidodont ? sp.
		Miolabis transmontanus Cope
		Alticamelus altus (Marsh)
Dromomeryx, near borealis (Cope)	Dromomeryx, near borealis (Cope)	Dromomeryx near borealis (Cope)
	Dromomeryx sp. b	Cervine (Palæomeryx ?) sp. a (possibly Dromomeryx)
		Cervine (Palæomeryx ?) sp. b (possibly Dromomeryx)
Blastomeryx ? sp.	Blastomeryx mollis Merriam	
Merycodus ? sp. a	Merycodus, near furcatus (Leidy)	
Merycodus ? sp. b	Merycodus nevadensis Merriam	

The Pawnee Creek Miocene of northeastern Colorado[1] is not far removed from the Skull Spring stage. *Tomarctus,* cf. *brevirostris* Cope, *Amphicyon sinapius* Matthew, *Euoplocyon* ? sp., *Mylagaulus,* cf. *lævis* Matthew and *Dromomeryx,* near *borealis* (Cope) from Skull Spring are forms which are also recognized in the Pawnee Creek fauna. The brachydont horses *Hypohippus* sp. and *Parahippus,* near *coloradensis* Gidley are close to *H. osborni* Gidley and *P. coloradensis* Gidley of the Colorado Miocene.

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[1] W. D. Matthew, Mem. Amer. Mus. Nat. Hist., vol. 1, Pt. 7, pp. 358-359, 373-374, 1901; Bull. Amer. Mus. Nat. Hist., vol. 16, pp. 281-290, 1902.

A close time relation is also seen to exist between the eastern Oregon fauna and that from the Lower Snake Creek beds of Nebraska.[1] The large fauna from the latter horizon includes most of the genera recorded from Skull Spring as may be seen by comparing the two lists given below.

SKULL SPRING	LOWER SNAKE CREEK
Carnivora	Carnivora
Tomarctus, cf. brevirostris Cope	Tomarctus brevirostris Cope
Canid ? sp.	Tomarctus temerarius (Leidy)
	Tomarctus confertus (Matthew)
	Tomarctus mortifer (Cook)
Amphicyon sinapius Matthew	Amphicyon sinapius Matthew
Amphicyon, cf. frendens Matthew	Amphicyon ingens Matthew
cf. Pliocyon medius Matthew	Pliocyon medius Matthew
Hemicyon n. sp.	
	Bassariscus antiquus Matthew and Cook
	Leptocyon vafer (Leidy)
Euoploycon ? sp.	Euoplocyon prædator Matthew
	Leptarctus primus Leidy
Mustelid n. sp.	Brachypsalis modicus Matthew
	Brachypsalis obliquidens Sinclair
	Mionictis incertus Matthew
	Mionictis elegans Matthew
	Plionictis glaræ (Sinclair)
	Plionictis parviloba (Cope)
	Sthenictis dolichops Matthew
	Metailurus intrepidus (Leidy)
Rodentia	Rodentia
Sciurus malheurensis n. sp.	
Sciurus tephrus n. sp.	
Citellus ridgwayi n. sp.	
Liodontia alexandræ (Furlong)	
Mylagaulus, cf. lævis Matthew	Mylagaulus lævis Matthew
	Mylagaulus paniensis Matthew
	Ceratogaulus rhinocerus Matthew
	Dipoides curtus Matthew and Cook
Diprionomys ? oregonensis n. sp.	Amblycastor fluminis Matthew
	Peridiomys rusticus Matthew
	Poamys rivicola Matthew
	Lagomorpha
	Hypolagus vetus (Kellogg)
	Insectivora
	Talpa incerta Matthew

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[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 59-73, 1924.

Skull Spring	Lower Snake Creek
Perissodactyla	Perissodactyla
Hypohippus sp.	Hypohippus osborni Gidley
	Hypohippus pertinax Matthew
Parahippus, near coloradensis Gidley	Parahippus integer Matthew
Merychippus isonesus (Cope)	Merychippus paniensis (Cope)
	Merychippus sejunctus (Cope)
	Merychippus proparvulus Osborn
	Merychippus campestris Gidley
	Merychippus eohipparion Osborn
Rhinocerotid sp.	Aphelops megalodus Cope
	Teleoceras medicornutus Osborn
Chalicothere ? sp.	
Artiodactyla	Artiodactyla
Platygonus ? sp.	Prosthennops sp.
Ticholeptus ? sp.	Merychyus sp.
	Metoreodon relictus Matthew and Cook
	Pronomotherium siouense Sinclair
	Protolabis fissidens (Cope)
	Protolabis angustidens (Cope)
	Alticamelus leptocolon Matthew
	Alticamelus procerus Matthew and Cook
Dromomeryx, near borealis (Cope)	Dromomeryx whitfordi Sinclair
Blastomeryx ? sp.	Blastomeryx elegans Matthew and Cook
	Blastomeryx (Dyseomeryx) sinclairi (Matthew)
Merycodus ? sp. a	Merycodus necatus Leidy
Merycodus ? sp. b	
	Cranioceras unicornis Matthew
	Drepanomeryx falciformis Sinclair

SYSTEMATIC DESCRIPTION OF MAMMALIAN FAUNA

CARNIVORA

The canid remains consisting of jaw fragments and isolated teeth indicate a varied group of forms. The author is indebted to Dr. Chester Stock for an identification of the specific relations of several of these forms and for a comparison of some of the material with type specimens in the collections of the American Museum of Natural History. A large part of the comparative descriptions were taken from Dr. Stock's notes.

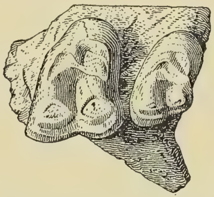
Tomarctus, cf. brevirostris Cope

A maxillary fragment with the two molars, No. 379 C. I. T. Coll. Vert. Pale. (fig. 2), has been referred to this species. A comparison of this specimen with skull No. 18242 Amer. Mus. Coll. labeled *Tomarctus* *brevirostris* Cope and described from the Lower Snake Creek beds [1] shows a similar arrangement of cusps in M1. In the latter specimen the teeth are slightly more worn than in No. 379. In the Skull Spring specimen the protocone, hypocone and metaconule are distinct. The protoconule, if present, was presumably a very small cusp and the wear may have obliterated its identity. A well-defined external cingulum is present and the principal external cusps appear to be slightly farther removed inwardly from the external border than in No. 18242 Amer. Mus. M2 is relatively larger than the corresponding tooth in the latter.

A comparison may also be made with skull No. 18244 Amer. Mus. Coll. from the Lower Snake Creek horizon, of which an excellent cast is available. The molars in this specimen of *Tomarctus brevirostris* are less worn than in No. 379 and are of about the same size and shape. M1 in No. 18244 Amer. Mus. has the inner cusps distinct and the antero-lateral corner of the tooth is nearly as angulate as in No. 379. The principal difference in the two teeth outside of wear is the slightly less transverse width in the Skull Spring M1.

No. 379 is also not far removed from *Tephrocyon rurestris* (Condon) [2] in size, but differs from this species in the shape of M1. The inner basin or heel of this tooth, according to the illustrations, is deflected more posteriorly in the type of *T. rurestris* than in No. 379. Also, the antero-external corner of the tooth is less angulate than in the Skull Spring form. However, the positions of the cusps are very similar in the two specimens. No noticeable difference occurs between the two second molars.

FIG. 2—*Tomarctus,* cf. *brevirostris* Cope. M1 and M2, No. 379 C.I.T. Coll., occlusal view; x 1.0. Skull Spring Miocene, Oregon.



Critical determination of relationships of *Tephrocyon* Merriam and *Tomarctus* Cope has not been made, although their generic identity has been suggested by Matthew.[3] The Skull Spring material does not assist materially in the solution of the problem.

	No. 379	No. 18242 Amer. Mus.	No. 18244 Amer. Mus.
	mm.	*mm.*	*mm.*
M1, greatest length along outer side	12.6	13.7	12.5
M1, greatest width normal to outer side	15.6	16.1	16.0
M2, greatest oblique diameter from outer side of paracone to inner side of hypocone	12.8	12.1	12.8
M2, greatest transverse diameter	7.8	7.2	7.8

[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 91-96, 1924.

[2] See J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 6-10, 1906; *ibid.,* vol. 7, pp. 362-364, 1913.

[3] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 88-91, 1924.

Euoplocyon ? sp.

A lower carnassial, No. 392 C. I. T. Coll. Vert. Pale. (fig. 3) is doubtfully referred to the genus *Euoplocyon* Matthew.[1] The specimen is a simple, narrow, three-cusped tooth, without metaconid. The heel is compressed antero-posteriorly, single-cusped and trenchant. The specimen shows characters similar to those seen in M$\overline{1}$ of *Cyon alpinus.*[2] No. 392 is a little more than half as large as *Euoplocyon magnus* (Thorpe).[3] Unfortunately, no illustrations or dimensions are given for the type lower jaw of *E. prædator* Matthew, except that it is much smaller than *E. magnus.*

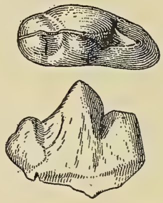


Fig. 3—*Euoplocyon* ? sp. Left lower carnassial, No. 392 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

The tooth presumably belongs to a form related to the *Cyon* group or Simocyoninæ. It is not so advanced nor so large as that in *Simocyon* or *Ischyrocyon* and differs from that in *Temnocyon* and *Philotrox* in the absence of a metaconid. No. 392 is similar to M$\overline{1}$ of *Enhydrocyon,* but is not so large and robust.

Some resemblance is also seen to the larger types of mustelids to which it may possibly be related rather than to the Canidæ. *Gulo* has a larger, relatively wider M$\overline{1}$ with higher paraconid and much lower talonid cusp. The heel of M$\overline{1}$ in the wolverine is not so trenchant and shows something of a postero-internal basin. Perhaps a greater similarity may be seen in a comparison of the tooth with M$\overline{1}$ in *Ælurocyon.* The lower carnassial of *A. brevifacies* Peterson[4] is only slightly larger than the Skull Spring tooth, but relatively wider, and has a cusp on the heel which is apparently higher than in *Gulo.* A noticeable difference from No. 392 is evident in that the heel seems to be expanded or offset inwardly in *Ælurocyon,* giving the tooth a more arcuate appearance.

M$\overline{1}$, anteroposterior length	17.9 *mm.*
M$\overline{1}$, greatest transverse width	7.7

Canid ? sp.

The specimen, No. 386 C.I.T. Coll. Vert. Pale. (fig. 4), which is here referred questionably to the Canidæ is a right lower jaw with a fourth premolar, the root portions of P$\overline{2}$, P$\overline{3}$, M$\overline{1}$ and M$\overline{2}$ and an alveolus for P$\overline{1}$. The specimen is broken away immediately behind the second molar. The presence of a third molar can not therefore be definitely determined. The size of M$\overline{2}$, which is a two-rooted tooth, may indicate that M$\overline{3}$ was present.

The form is characterized by an unusually deep ramus for the length of the tooth row. P$\overline{2}$, P$\overline{3}$ and P$\overline{4}$ are two-rooted and anteroposteriorly compressed. P$\overline{4}$ is a simple, conical tooth with a heavy cingulum completely surrounding the base. The anterior, posterior and inner margins of the cone are rather angulate, giving the tooth a triangular outline with a convex outer side in dorsal view. The carnassial tooth was large, more than twice as long as the fourth premolar, and possessed sturdy well-separated roots. The second molar was wider transversely across the anterior portion than across the posterior root. The tooth was probably less than two-thirds as wide as it was long. As inferred from the posterior convergence of M$\overline{2}$, the third molar if present was probably of reduced size. The posterior mental foramen is located below P$\overline{4}$, the anterior below a point between P$\overline{2}$ and P$\overline{3}$.

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[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 103-104, 1924.

[2] See J. L. Wortman and W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 12, pp. 115-118, fig. 2, 1899.

[3] M. R. Thorpe, Amer. Jour. Sci., ser. 5, vol. 3, pp. 440-443, 1922.

[4] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 68-72, 1908.

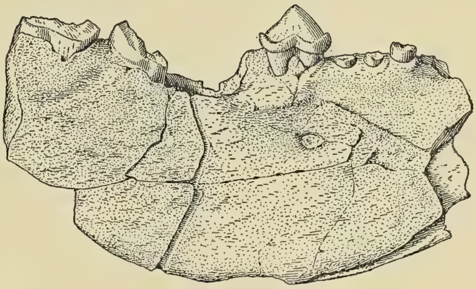

FIG. 4—*Canid* ? sp. Right ramus of mandible with P$\overline{4}$ and the root portions of P$\overline{2}$, P$\overline{3}$, M$\overline{1}$ and M$\overline{2}$, No. 386 C.I.T. Coll., lateral view; x 1.0. Skull Spring Miocene, Oregon.

In many features, as pointed out by Dr. E. R. Hall,[1] the specimen resembles the lower jaw of the mustelid, *Ælurocyon brevifacies* Peterson [2] as for example in anteroposterior compression of the dental series, relative depth of jaw and in massiveness of the carnassial. However, a number of rather important differences between the two forms are noted. The Skull Spring specimen is much smaller, the premolars are simpler and more compressed anteroposteriorly, and the second molar is decidedly larger and perhaps more canid-like.

As to whether this specimen represents the same form as the carnassial which has been referred questionably to *Euoplocyon* there is at present no means of telling. The carnassial No. 392 is of the same size as that indicated by roots of M$\overline{1}$ in No. 386, but P$\overline{4}$ in No. 386 has a heavy cingulum while M$\overline{1}$, No. 392, lacks this character. However, if the two are found to represent the same form, the generic relationship of the Skull Spring type to *Euoplocyon* would probably not be close, inasmuch as P$\overline{4}$ in No. 386 does not conform to the characters of the comparable tooth in the latter genus.

Depth of ramus below P$\overline{4}$	*a*30. *mm.*
P$\overline{2}$ to M$\overline{2}$, greatest length	*a*54.
P$\overline{2}$ to P$\overline{4}$, greatest length	*a*23.
P$\overline{4}$, anteroposterior diameter	9.
P$\overline{4}$, transverse diameter parallel to outer wall	5.4
M$\overline{1}$, anteroposterior diameter	*a*19.5
M$\overline{2}$, anteroposterior diameter	*a*11.

a, approximate.

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[1] Oral communication.

[2] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 68-72, 1908.

Amphicyon sinapius Matthew

Among the teeth referred to *Amphicyon* there are two lower molars which resemble more nearly *A. sinapius* than any of the other species so far described. The tooth crown, No. 374 C. I. T. Coll. Vert. Pale. (fig. 5*a*). belongs to a second molar of a left ramus. This specimen is only slightly smaller than the type of *A. sinapius,* No. 9358 Amer. Mus. from the Pawnee Creek beds of Colorado.[1] As in *Amphicyon* the three prominent cusps are the protoconid and metaconid in front and the hypoconid behind. In the Skull Spring specimen the summits of the protoconid and metaconid are less widely separated in transverse direction than in the type of *A. sinapius.* In the Oregon tooth the anteroexternal corner of the tooth is extended more forward and the surface of the protoconid slopes more gradually than in the type. The forward projection of this region of the tooth makes the anteroposterior diameter along the outer side much more than that along the inner side.

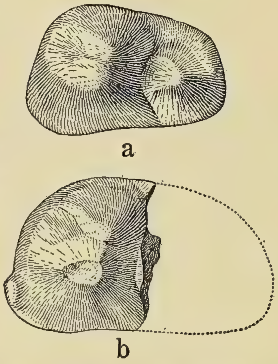

FIG.5, *a* and *b*—*Amphicyon sinapius* Matthew. *a,* M$\overline{2}$ of left ramus, No. 374 C.I.T. Coll., occlusal view; *b,* fragmentary M$\overline{2}$ of left ramus, No. 375 C.I.T. Coll., occlusal view; x 1.0. Skull Spring Miocene, Oregon.

No. 375 (fig. 5*b*) is apparently the forward half of M$\overline{2}$ of a left ramus. This tooth is noticeably larger than No. 374, but has essentially the same pattern developed on the occlusal surface as in the latter. As in No. 374, also, the anterior end is obliquely truncated, giving prominence to the anteroexternal corner. A small cuspule is present on the cingulum in this region of the tooth. The fang supporting the protoconid-metaconid region of the tooth-crown was presumably not so large as that supporting the posterior portion. There is evidence to show that a fusion of two roots characterizes the anterior fang.

This Skull Spring form is not far removed from *A. sinapius* of the Pawnee Creek and from the Amphicyonines of the Snake Creek referred by Matthew to this species.

Comparative Measurements

	No. 374 C. I. T.	No. 375 C. I. T.	Type No. 9358 Amer. Mus.	No. 18258 Amer. Mus.
	mm.	*mm.*	*mm.*	*mm.*
M$\overline{2}$, greatest length measured along outer side........................	26.0	....	27.1	25.0
M$\overline{2}$, greatest width normal to outer side............................	17.0	20.0	18.1	17.6

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[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 16, pp. 288-289, 1902.

Amphicyon, cf. frendens Matthew

The inner half of an upper molar and the trigonid of a lower carnassial are considered as representing another species of *Amphicyon,* possibly *A. frendens.* The carnassial, No. 376, C. I. T. Coll. Vert. Pale. (fig. 6*a*), is noticeably larger than the cotype of *A. sinapius,* No. 9357 Amer. Mus. from the Pawnee Creek beds. The latter represents an unworn crown of $M\overline{1}$.[1] In character of size, No. 376 is more nearly like the type *A. frendens,* No. 18913 Amer. Mus. One noticeable difference between the Oregon specimen and the comparable tooth in *A. sinapius* and *A. frendens* is presented by the transverse width taken through the notch separating paraconid from protoconid. With greater prominence of the external border of this tooth opposite the notch, the transverse diameter at this point is greater in the Skull Spring tooth. Moreover, the external border at this point turns more sharply inward toward the anterior end of the tooth. As in *Amphicyon* the paraconid and protoconid form a heavy shearing blade, and the metaconid is relatively small. No. 376 is distinctly smaller than an $M\overline{1}$ referred to *A. ingens.*

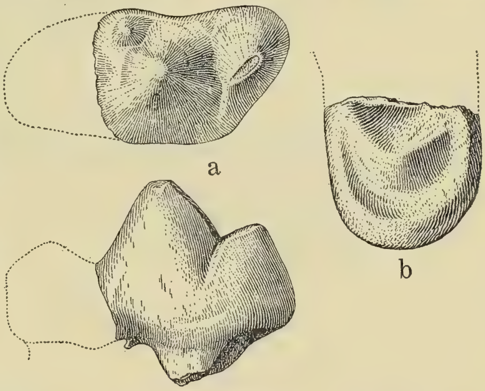

FIG. 6, *a* and *b*—*Amphicyon,* cf. *frendens* Matthew. *a,* Trigonid of right lower carnassial, No. 376 C.I.T. Coll., lateral and occlusal views; *b,* inner half of upper molar, No. 377 C.I.T. Coll., occlusal view; x 1.0. Skull Spring Miocene, Oregon.

The inner half of the upper molar, No. 379 (fig. 6*b*), presumably from the right side, resembles more closely $M\underline{2}$ than $M\underline{1}$. This resemblance is shown by the lowness of the inner ledge of the tooth and by the lowness of the protocone. Moreover, in the tooth fragment, the protocone is farther removed from the inner ledge toward the external side as in $M\underline{2}$. In $M\underline{1}$ the cusp approaches more closely the internal cingulum. In $M\underline{1}$ of *Amphicyon frendens* the intermediate cuspules (protoconule and metaconule) are distinctly larger and better defined than in $M\underline{2}$. While only the inner half of the tooth is present in the Skull Spring specimen, it would appear that distinct cusps representing the protoconule and metaconule and having positions at each end of the protocone crescent are absent. In this respect the Skull Spring type resembles $M\underline{2}$, No. 18914, described but not figured by Matthew under the species *Amphicyon frendens.*

In size, No. 379 resembles most closely *A. frendens* and is distinctly larger than *A. idoneus.* The tooth fragment is actually larger than the corresponding portion of $M\underline{2}$, No. 18914 Amer. Mus. referred to *A. frendens.* The fang supporting this section of the tooth is also heavier than in the Snake Creek specimen. It is larger than the corresponding part of $M\underline{2}$ in *A. sinapius,* skull No. 18257 Amer. Mus. from Snake Creek. In the Oregon

[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 16, p. 289, fig. 4, 1902.

specimen the protocone crescent is low, much more so than in the type of *A. frendens,* No. 18914 Amer. Mus., and in this respect No. 379 resembles more closely No. 18914 Amer. Mus. which has been referred to the same species. The crown is more deeply excavated along the inner border of the protocone crescent in the specimen from the Skull Spring horizon. The form of the inner cingulum resembles that in No. 18914.

Comparative Measurements

	No. 376 C.I.T.	A. sinapius No. 9357 Cotype Amer. Mus.	A. referred to sinapius No. 18258 Amer. Mus.	A. frendens No. 18913 Type Amer. Mus.
	mm.	*mm.*	*mm.*	*mm.*
M$\overline{1}$, anteroposterior diameter from base of metaconid to anterior end of tooth..................	25.5	23.5	23.4	25.7
M$\overline{1}$, transverse diameter at posterior end of base of protoconid..	17.5	15.0	*a* 17.4	20.4
M$\overline{1}$, transverse diameter through notch between paraconid and protoconid....................	17.0	14.3	14.6	15.7
		No. 379 C.I.T.	No. 18914 Amer. Mus.	
M$\underline{2}$, anteroposterior diameter of inner heel......................	....	20.6	18.7	

a, approximate.

Cf. Pliocyon medius Matthew

Among the materials representing the larger canids in the fauna is the heel portion of a lower carnassial, No. 378 C. I. T. Coll. Vert. Pale. (fig. 7), showing a large hypoconid and a subdued entoconid ridge. The crown is supported by a heavy fang or root. This specimen is distinctly smaller than the corresponding portion of M$\overline{1}$ in the cotype of *Amphicyon sinapius*, in No. 18258 Amer. Mus. referred to this species, and in *A. frendens*. In point of size, it comes closest to *Pliocyon medius* Matthew,[1] No. 13848

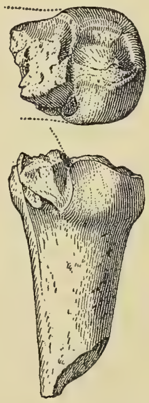

Fig. 7—Cf. *Pliocyon medius* Matthew. Heel of left lower carnassial, No. 378 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

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[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 38, pp. 190-194, 1916; Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 113-128, 1924.

and No. 13847 Amer. Mus. Coll. The character of the heel and the position of the hypoconid is much the same as in these specimens. The entoconid ridge is similar to that in No. 13848 Amer. Mus.

Comparative Measurements

	No. 378 C.I.T.	No. 13848 Amer. Mus.	No. 13847 Amer. Mus.
	mm.	*mm.*	*mm.*
$M\overline{1}$, width of heel	14.1	14.7	14.4
$M\overline{1}$, anteroposterior diameter from anterior end of hypoconid to posterior end of tooth	9.6	10.9	11.2

Apparently the Skull Spring locality has yielded a record of the *Amphicyon* group which in its diversity resembles somewhat that of the Lower Snake Creek of Nebraska. Comparable lists of species from the two horizons are given below:

SNAKE CREEK	SKULL SPRING
A. sinapius	A. sinapius
A. frendens	A., cf. frendens
A. idoneus	
A. ingens	
Pliocyon medius	cf. Pliocyon medius

Hemicyon ? n. sp.

A small upper carnassial (fig. 8) in the collection resembles very strongly the corresponding tooth in the Hemicyoninæ. The specimen is intermediate in size between *Ursavus primœvus* (Gaillard) [1] and *Hemicyon barstowensis* Frick. [2] From the latter species it differs mainly in the larger and slightly more prominently projecting protocone. A slight but well-defined cingulum is present externally along the base of the paracone-metacone blade. The internal cingulum is even better defined. The forward border of the protocone is rather sharply demarcated from the inner anterior border of the paracone, distinctly more so than in *H. barstowensis*. The posterior end of the protocone reaches backward to a point slightly in advance of the notch between paracone and metacone. Its position with reference to the paracone does not differ noticeably from that in *H. barstowensis*. The external wall of the paracone-metacone blade appears slightly more indented toward the notch than in *H. barstowensis*. This indentation is less noticeable in *Ursavus*.

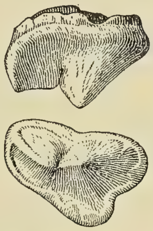

FIG. 8—*Hemicyon* ? n. sp. Right upper carnassial, No. 380 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

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[1] See J. W. Gidley, Jour. Mammal., vol. 4, pp. 240-243, 1923.

[2] Childs Frick, Bull. Amer. Mus. Nat. Hist., vol. 56, pp. 27-34, 1926.

Possibly No. 380 represents a deciduous carnassial of *Hemicyon* or of *Amphicyon,* but the very strong resemblance between this tooth and P$\underline{4}$ in *Hemicyon barstowensis,* No. 20821 Amer. Mus., makes the probability of relationship to the amphicyonine dogs seem rather remote.

No. 380 may represent the earliest occurrence of the genus *Hemicyon* in America. It is apparently earlier than the species described from the Barstow or Santa Fé stages. However, a lower jaw from the Pawnee Creek beds in northeastern Colorado, named *Ursavus pawniensis* by Frick,[1] is from approximately the same stage in the Miocene.

Comparative Measurements

	No. 380 C.I.T.	Type No. 20810 H. barstowensis	Cast of No. 20821 H. barstowensis	Cast of No. 17729 Ursavus primævus
	mm.	*mm.*	*mm.*	*mm.*
P$\underline{4}$, anteroposterior diameter.........	19.4	22.1	21.9	12.9
P$\underline{4}$, greatest width across protocone...	12.8	13.3	13.3	8.4
P$\underline{4}$, length of metacone blade.........	7.1	8.4	8.3	4.2

Mustelid[2] n. sp.

Dr. E. R. Hall of the Museum of Vertebrate Zoology, University of California, has kindly consented to examine and report on a mustelid lower jaw, No. 391, in the Skull Spring collection. A skull fragment, No. 393, without teeth may represent the same form. The following tentative statement is a part of a communication from Dr. Hall and is included here pending a more complete published report on this form:

"The fragment of left lower jaw bearing M$\overline{1}$, P$\overline{3}$ and the alveoli of P$\overline{4}$ seems to represent an undescribed species of mustelid intermediate in character as between *Mustela* on the one hand and *Plionictis* and *Martes* on the other. Outstanding characters are the short, fully trenchant talonid of M$\overline{1}$, recalling the condition seen in *Mustela,* but with a distinct, although weakly developed, metaconid on this tooth which occurs in *Martes* but not in *Mustela.* M$\overline{1}$ is small relative to the depth of the lower jaw. P$\overline{3}$ is relatively larger than in *Mustela* but relatively smaller than in *Martes,* thus suggesting that the Skull Spring animal was intermediate to *Martes* and *Mustela* in reduction of the premolars. M$\overline{1}$ is 8.4 mm. long. P$\overline{3}$ is 4.3 mm. long. The jaw itself represents an animal very like *Mustela nigripes* in general size, but with relatively, and actually, smaller teeth."

RODENTIA

Sciurus malheurensis n. sp.

Holotype—No. 129 C. I. T. Coll. Vert. Pale., a skull with the superior dentition.

Paratype—No. 333, a skull without dentition.

Specific characters—Skull moderately large and robust. Rostrum deep and broad. Palate and ventral surface of muzzle wide. Acute portion of zygomatic ridge does not extend anteriorly so far as the dorsal surface of muzzle. Cranium comparatively small and dorsally flat. Basi-occipital region relatively high and narrow. Diastema between I and P$\underline{3}$ long. Fossæ are present posterior to incisors and antero-lateral to anterior palatine foramina. Teeth relatively small, quadrate and of a modern type with four prominent transverse lophs and no indication of a fifth median ridge.

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[1] Childs Frick, Bull. Amer. Mus. Nat. Hist., vol. 56, pp. 106-110, 1926.

[2] This form has now been described as *Martes (Tomictis) gazini* Hall in Jour. Mammal., vol. 12, pp. 156-157, pl. 5, figs. *a-b,* 1931.

Material—The material representing this species consists of the two skulls Nos. 129 and 333. The type specimen is the anterior portion of a skull with most of the dentition (see plate 1, figs. 1 and 1*a*). The right grinding series is complete from P$\underline{4}$ to M$\underline{3}$, lacking only P$\underline{3}$. The left series is not so complete, M$\underline{2}$ and M$\underline{3}$ being the only undamaged teeth. The premaxillaries are well preserved around the incisive alveoli, but the incisors themselves are absent. The paratype is the posterior portion of a skull without teeth (see plate 2, fig. 3). The specimen is not particularly well preserved, inasmuch as the bone has flaked off in many places, exposing a cast of the brain chamber. However, the specimen shows the shape of the brain cavity and the proportions of the occipital region. Also, the position and size of the tympanic bullæ are determinable.

Description—*Sciurus malheurensis* is a large robust squirrel approaching *S. aberti* and *S. niger* in size but smaller than *S. griseus*. The rostrum of No. 129 is broad and deep as in these species, resembling also the Central American form *S. variegatoides* in width of ventral surface of the muzzle. A rather conspicuous feature is the posterior position of the grinding teeth, permitting a very long diastema between the incisor and third premolar. In length of the diastema No. 129 is close to *S. griseus* and far removed from *S. variegatoides*. In association with the posterior position of the cheek-teeth the maxillary portion of the zygoma of No. 129 expands laterally above P$\underline{4}$, whereas in Recent forms the ventral margin of the expansion is above M$\underline{1}$ or perhaps at a point midway in the series. The maxillary portion of the zygoma does not extend as an acute ridge to the dorsal surface of the muzzle as in Recent individuals but passes anteriorly into a rounded bulge about midway between the dorsal and ventral sides.

The dorsal surface of the skull of *S. malheurensis* is noticeably flat, more so than in Recent species of comparable size. This flatness is conspicuous in No. 333 where it is carried backward nearly to the supra-occipital. In a longitudinal profile the Recent skulls are much more convex in the vicinity of the parietals and the posterior portion of the frontals. Accompanying this convexity is the appreciably lower position of the basi-occipital region, more so than in No. 333. Furthermore, behind the rostrum the skulls of Recent forms become very much wider than in *S. malheurensis*. Corresponding to the smaller size of the cranium in the fossil, the occipital region is narrower and the bullæ are closer together than in Recent types having a rostrum of nearly comparable size.

In many respects, as in the characters mentioned above, the skull of *S. malheurensis* resembles that of the Eocene rodent, *Paramys*.[1] This resemblance is most marked in size and shape of cranium, although the brain-case is proportionately larger and a sagittal crest is probably not developed in the Miocene squirrel. *S. malheurensis* is removed from the Eocene forms in other characters, as for example in progressive development of the dentition, apparent ossification of the bullæ, anterior development of the zygoma and in the character of the infra-orbital foramen. The infra-orbital foramen in No. 129 is anteriorly placed as in Recent tree squirrels, and the ventro-lateral margin of the anterior opening is well developed, but not nearly so much as in the ground squirrels.

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[1] See W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, pp. 45-59, 1910.

The upper teeth in No. 129 from Skull Spring are distinctly smaller than the teeth examined in Recent sciurids of corresponding size. The length of the tooth-row in *S. malheurensis* corresponds to that in the smaller species *S. deppei.*

The individual teeth are quadrate, with four rather prominent transverse crests or lophs. The lophs and basins, however, are not so accentuated as in Recent citellids. The ridges all unite in the protocone internally and terminate externally in the marginal cusps. The anterior crest or style is convex forward, particularly in M$\underline{1}$, and approaches the paracone externally, from which it is separated by a notch. The second loph is nearly straight and terminates in the paracone. A protoconule is not distinguishable on this ridge. The third loph is slightly convex posteriorly and unites directly with the metacone. The metaconule is conspicuous in this ridge, more so than in Recent individuals. The posterior crest is directed backward and outward from the protocone and unites directly with the posterior flank of the metacone. A small cuspule may be present between the paracone and metacone as in M$\underline{1}$.

Relationship—Among the rodents of the North American Tertiary the squirrel types of the Miocene and Pliocene are as yet known by incomplete material. An occasional lower jaw or skull fragment represents the material on which rest the stages which have been recognized between the Eocene and Quaternary forms. Since the Sciuridæ form a rather primitive group, marked resemblances to the Ischyromyidæ are to be noted. Fossil squirrels described from formations ranging in age from upper Oligocene to Pliocene inclusive tend to establish this connection. The material, however, is far too scanty to permit the recognition of the various phyletic series which must have existed with the development of the group in later Tertiary time.

The larger specimen from Skull Spring retains certain features, particularly in the cranial region of the skull, which remind one of an ischyromyid ancestry, although these are associated with characters in the dentition which are decidedly modern. This form may be in or near the line of descent of modern forms, but until more is known of the various stems still living and extinct its position remains uncertain.

A comparison of *S. malheurensis* with middle Tertiary members of the genus *Sciurus* is difficult because many of the types are known only by the lower jaw.

S. arctomyoides Douglass[1] from the Madison Valley beds in Montana is a very much larger form as indicated by the length of the lower tooth series. *S. ballovianus* Cope[2] from the John Day beds of Oregon is decidedly smaller and differently proportioned, having a short and relatively broad cranium. *S. vortmani* Cope[3] also from the John Day deposits and *S. relictus* Cope[4] from the White River beds of Colorado can not be compared satisfactorily with the Skull Spring form because of absence of similar material. *S. vortmani* may be near the same size as indicated by the length of the lower tooth-row. On a similar basis *S. relictus* appears to be a smaller form.

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[1] Earl Douglass, Ann. Carnegie Mus., vol. 2, pp. 181-182, 1903.

[2] E. D. Cope, Rept. U. S. Geol. Surv. Terrs., vol. 3, pp. 818-819, 1884.

[3] E. D. Cope, *ibid.*, pp. 816-817.

[4] E. D. Cope, *ibid.*, pp. 817-818.

Comparative Measurements

	S. malheurensis		S. griseus No. 9601*	S. aberti No. 6817*
	No. 129 C.I.T.	No. 333 C.I.T.		
	mm.	*mm.*	*mm.*	*mm.*
Distance from posterior margin of anterior palatine foramina to tip of occipital condyles	....	43.5	49.2	43.9
Greatest width of cranium not including zygomatic portion of squamosal	....	*a* 21.5	28.8	26.8
Width between outer surfaces of bullæ	....	20.0	25.0	24.1
Anteroposterior length of bullæ	....	11.0	12.3	11.0
Depth of muzzle below nasofrontal suture	16.1	15.0–16.0	18.3	15.1
Width of dorsal surface of muzzle across anterior palatine foramina	7.7	*a* 7.7	7.5–8.5	7.5–8.0
Width of palate between M$\underline{1}$	8.2	*a* 8.	7.9	8.1
Length of diastema between I and P$\underline{3}$	*a* 15.4	....	15.4	15.0
Distance between posterior margin of anterior palatine foramen and P$\underline{3}$	10.1	*a* 10.0	9.1	8.7
P$\underline{3}$-M$\underline{3}$, greatest length	*a* 10.5	....	12.5	11.5
P$\underline{4}$-M$\underline{3}$, greatest length	9.1	....	11.7	11.0
I, anteroposterior diameter	*a* 4.3	....	3.6	3.1
I, greatest transverse diameter	*a* 2.4	....	1.8	2.0
P$\underline{4}$, anteroposterior diameter	2.0	....	2.4	2.5
P$\underline{4}$, greatest transverse diameter	2.4	....	2.7	2.4
M$\underline{1}$, anteroposterior diameter	2.4	....	2.9	2.5
M$\underline{1}$, greatest transverse diameter	2.7	....	3.3	3.1
M$\underline{2}$, anteroposterior diameter	2.3	....	3.1	2.7
M$\underline{2}$, greatest transverse diameter	2.8	....	3.5	3.1
M$\underline{3}$, anteroposterior diameter	2.5	....	3.3	3.2
M$\underline{3}$, greatest transverse diameter	2.5	....	3.3	3.2

a, approximate.
* Recent skulls from Donald R. Dickey Collection.

Sciurus tephrus n. sp.

Holotype—No. 332 C. I. T. Coll. Vert. Pale., a skull with right superior dentition.

Specific characters—Skull small and slender. Muzzle relatively long, deep and narrow. Zygomatic ridge as in *S. malheurensis* and does not extend anteriorly to the dorsal surface of rostrum. Diastema between I and P$\underline{4}$ elongate, equaling in length that in *S. deppei.* Fossæ posterior to incisors and antero-lateral to anterior palatine foramina are shallow. Teeth near *S. hudsonicus* in size but P$\underline{4}$ short anteroposteriorly.

Material—This form is represented by the greater portion of a skull with the grinding teeth P$\underline{4}$ to M$\underline{3}$ complete on the right side (see plate 1, figs. 2, 2*a* and 2*b*). The third premolar is absent and its alveolus is indistinct, but a tooth may have been present during the life of the animal. The posterior part of the skull and the zygomatic arches have not been preserved.

Description—*S. tephrus* is a small, slender form nearest in size to *S. hudsonicus* and *S. douglassii* among the Recent species. The rostrum is relatively long, deep and narrow. The palate also appears to be rather narrow, but this may be due in part to crushing. The maxillary portion of the zygoma rises anteriorly as a ridge, reaching approximately between the dorsal and ventral sides as in *S. malheurensis*. This ridge is similarly developed in *Ischyromys,* but less so in *Paramys*. In Recent individuals the ridge rises well toward the dorsal surface of the muzzle. The anterior opening of the infra-orbital foramen is a vertical slit placed well ahead of P4. The ventro-lateral portion of the margin of this opening is prolonged ventrally into a small knob which, however, is not so conspicuous as in the citellids. The fossæ posterior to the incisors and antero-lateral to the anterior palatine foramina are present but less developed than in *S. malheurensis*. The diastema between the incisor and fourth premolar is very long in proportion to the size of the skull, approaching that in the larger *S. deppei*.

The cheek-teeth in No. 332 are of moderate size and exhibit considerable wear. The enamel of the occlusal surface in these teeth has been almost entirely worn away. The cusps and crests are subdued and are formed only of dentine, except around the margins of the teeth. P$\underline{4}$ is a small tooth compressed anteroposteriorly with only two transverse ridges of any prominence. The anterior and posterior marginal crests in this tooth are very much reduced. M$\underline{1}$ and M$\underline{2}$ are more quadrate than P4 and show four transverse crests, of which the fourth or posterior crest is much reduced. On the external margin of these two teeth there is evidence of a small cuspule between the paracone and metacone. M$\underline{3}$ has a prominent crest extending from the protocone to the paracone, with a low marginal ridge of enamel anterior to this. Posterior to the principal ridge is the basined heel. In none of the teeth is there an indication of a distinct protoconule.

Relationships—The difficulty of making adequate comparisons with other Tertiary forms is encountered likewise in a study of the relationships of *S. tephrus*. Because of lack of comparable material, neither the John Day species nor the White River form permit of ready comparison with the type from Skull Spring. Where materials consist only of lower jaw fragments, size becomes the only character on which a comparison can be made.

S. tephrus differs from *S. malheurensis* in several characters, notably in much smaller size. This can not be due to difference in age, inasmuch as the tooth rows are not of comparable length and No. 332 is an old individual. Secondly, the rostrum, though deep, is slender and relatively narrow dorsally, whereas in *S. malheurensis* the rostrum is robust and broad. Thirdly, the diastema between the incisor and P$\underline{4}$ though long in both forms is somewhat shorter in proportion to the length of tooth-row in *S. tephrus*. Fourthly, the fossæ posterior to the incisors are not so well developed in the small form. Lastly, while the pattern of the teeth can not be compared, due to great difference in wear, the anterior grinders are relatively shorter anteroposteriorly in *S. tephrus*.

The position of this form in the phylogenetic series of sciurids is also indefinite. *S. tephrus* may be ancestral to some of the smaller species of living forms, but there is as yet no good evidence to show that modern species originated separately as far back as perhaps middle Miocene time.

Comparative Measurements

	S. tephrus No. 332 C.I.T.	S. malheurensis No. 129 C.I.T.	S. hudsonicus No. 6813*	S. douglassii No. 8706*
	mm.	*mm.*	*mm.*	*mm.*
Depth of muzzle below naso-frontal suture.......	*a* 11.5	16.1	11.8	11.2
Length of diastema between I and P4..........	12.4	16.8	10.8	11.4
Distance between posterior margin of anterior palatine foramen and P4.....	7.0(?)	11.2	7.5	7.7
Width of dorsal surface of muzzle across anterior palatine foramina........	5.0–6.0	7.7	*a* 5.0	*a* 5.0
P4 to M3, greatest length...	6.9	9.1	7.2	8.0
I, anteroposterior diameter.	2.9	*a* 4.3	2.5	2.5
I, greatest transverse diameter....................	1.6	*a* 2.4	1.4	1.4
P4, anteroposterior diameter	1.4	2.0	1.7	2.1
P4, greatest transverse diameter.................	1.8	2.4	1.8	2.3
M1, anteroposterior diameter	1.8	2.4	1.8	1.9
M1, greatest transverse diameter.................	2.1	2.7	2.1	2.4
M2, anteroposterior diameter	1.8	2.3	1.8	2.1
M2, greatest transverse diameter.................	2.2	2.8	2.3	2.6
M3, anteroposterior diameter	2.1	2.5	2.1	2.3
M3, greatest transverse diameter................	2.0	2.5	2.0	2.3

a, approximate.
* Recent skulls from Donald R. Dickey Collection.

Citellus ridgwayi[1] n. sp.

Holotype—No. 334 C. I. T. Coll. Vert. Pale., a skull with superior dentition.

Specific characters—Skull broad and shallow. Size and length of tooth-row near *Callospermophilus chrysodeirus.* Palate wide and diastema between I and P3 long. Teeth not so progressive as in typical citellids. P3 with simple, conical crown. P4 short anteroposteriorly and with two lophs. M1 and M2 broad, with two prominent lophs of moderate height and with one less prominent crest in front.

Material—The type specimen, No. 334, is the front portion of a skull which extends backward to the anterior wall of the brain-case (see plate 2, figs. 1 and 1*a*). The rostrum is somewhat distorted, the left side having been elevated with respect to the right. A good portion of the right zygoma has been preserved, but very little of the left. The cheek-teeth on the right side are well preserved, but those on the left, except P3 and P4, were exposed and have been somewhat weathered. The incisors have been broken down nearly to the alveolar rims.

A second skull, No. 335 (see plate 2, figs. 2 and 2*a*), which has been referred to this species is more complete but the preservation is not so good as in No. 334. A larger portion of the cranium is present, but the anterior cheek-teeth, P4 and M1, on both sides are absent or poorly preserved.

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[1] Named for John L. Ridgway.

A fragment of the maxillaries and frontals of another individual, No. 336, retains the three molar teeth on the right side. The specimen has been referred to *C. ridgwayi* on the basis of the depth of the skull and size of the teeth.

Description—Citellus ridgwayi is a small ground squirrel resembling closely in size *Callospermophilus chrysodeirus* among the Recent forms. No. 334 has the typical shallow muzzle of the citellids, which is ventrally broad in the vicinity of the anterior palatine foramen as well as between the cheek-teeth. No. 335 is similar to the Recent form *C. chrysodeirus* in many respects, as in the shape and position of the zygomatic arch, the shape of the anterior portion of the cranium and the length of the tooth-row. The muzzle in *C. ridgwayi* is slightly shallower toward the rear than *C. chrysodeirus,* and has a longer diastema between the cheek teeth and incisors. The dorsal surface of the skull in No. 335 is less convex longitudinally than in the Recent form, a character which was also noticed in a comparison of *Sciurus malheurensis* with Recent forms. The dorsal surface is also wider between the orbits in both Nos. 334 and 335 than in *C. chrysodeirus.* The outer and anterior margin of the zygoma in No. 334 continues forward on the side of the muzzle as a small ridge, following the contour of the incisor to the alveolus. This ridge is subdued in modern citellids and may not be continuous with the zygoma. The projection from the ventro-lateral margin of the infra-orbital foramen is conspicuous in No. 334.

The cheek-teeth in the type specimen are well worn, but the cusps and lophs are still pronounced. The pattern of the teeth resembles to some extent that in living citellids. Although the transverse lophs are well developed, the teeth show a closer resemblance to *Sciurus* than do the teeth in modern individuals. The teeth are relatively broad transversely in comparison to their length and approach the nearly triangular outline of Recent citellid teeth.

P$\underline{3}$ in No. 334 is a simple, conically crowned tooth, rather robust as in most ground squirrels. P$\underline{4}$ is short anteroposteriorly but wide transversely, and has only two crests developed. There is present on the outer enamel of this tooth a very small cuspule between the paracone and metacone. This cuspule is also present in M$\underline{1}$ but not in the other teeth. M$\underline{1}$ and M$\underline{2}$ are relatively wide teeth. The two central lophs, terminating laterally in the paracone and metacone respectively, are well developed with no indication of a distinct metaconule on the latter ridge, at least not in the present state of wear. The anterior style on the enamel margin of these two teeth is moderately prominent, but the posterior margin is subdued, giving the teeth a three-ridged appearance. While the posterior ridge is often prominent in *Sciurus,* and likewise in a few citellids, the reduction of that ridge appears to be associated with the development of a triangular shaped tooth. M$\underline{3}$ has the usual expanded posterior basin or heel. The protocone-paracone loph is prominent and there is also a ridge running through the posterior heel to the metacone. In the last upper molar of No. 335 this ridge to the metacone is not shown. Modern citellids may have a cusp (metaconule) in this basin and perhaps one or two cuspules on the margin between paracone and metacone.

Relationships—Compared with *C. (Protospermophilus) quatalensis* Gazin,[1] *C. ridgwayi* is less robust, decidedly smaller and has somewhat more modernized teeth. The two species undoubtedly belong to different subgroups, but their position in the phylogenetic tree is not definitely known. *C. (P.) quatalensis,* although more primitive, comes apparently from younger beds than the species *C. ridgwayi* and hence can not belong with the latter in the same phyletic line. The resemblances of the two forms, one to *Otospermophilus* and the other to *Callospermophilus,* might suggest their positions in the phylogenetic series. The close relationship existing between these living groups obviates, however, the possibility of independent origin of the types in less closely related Miocene forms.

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[1] C. L. Gazin, Carnegie Inst. Wash. Pub. No. 404, pp. 64-66, 1930.

C. ridgwayi differs from *C. cochisei* Gidley[1] from the Pliocene San Pedro Valley beds of Arizona in smaller size. The upper teeth in the former species are of relatively greater anteroposterior diameter and P$\underline{3}$ is less developed than in *C. cochisei.*

Adequate comparisons can not be made with *C. bensoni* Gidley,[2] also from the San Pedro Valley beds, inasmuch as the upper jaw material of this form is very fragmentary. The paratype, which is a lower jaw, indicates a much larger species than *C. ridgwayi.*

Both of the San Pedro Valley forms are more advanced than *C. ridgwayi,* in possessing comparatively modern dentitions. *C. cochisei* has a dentition approaching that in typical citellids in relative anteroposterior compression of the teeth. As mentioned by Gidley, there is also some resemblance to *Cynomys. C. bensoni* is near *C. beecheyi,* according to Gidley, and hence falls possibly in the subgenus *Otospermophilus.*

Comparative Measurements

	C. ridgwayi		C. (P.) quatalensis No. 30	C. chrysodeirus No. J902*
	No. 334	No. 335		
	mm.	*mm.*	*mm.*	*mm.*
Depth of skull from frontals to palate between M$\underline{1}$	....	9.4	10.0 (?)	10.1
Width of palate between M$\underline{1}$	*a* 6.9	6.9	8.2	11.3
Length of diastema between I and P$\underline{3}$	*a* 13.1	....	11.4	10.7
P$\underline{3}$ to M$\underline{3}$, greatest length	7.9	*a* 7.9	10.2	7.9
I, anteroposterior diameter	*a* 2.8	*a* 2.7	*a* 3.4	1.9
I, greatest transverse diameter	1.9	*a* 1.9	1.9	1.4
P$\underline{3}$, greatest diameter	0.7	....	0.6	1.1
P$\underline{4}$, anteroposterior diameter	1.6	....	2.0	1.8
P$\underline{4}$, greatest transverse diameter	2.0	....	2.5	2.2
M$\underline{1}$, anteroposterior diameter	1.9	*a* 1.8	2.2	1.8
M$\underline{1}$, greatest transverse diameter	2.4	*a* 2.3	2.6	2.3
M$\underline{2}$, anteroposterior diameter	2.0	2.0	2.3	1.9
M$\underline{2}$, greatest transverse diameter	2.4	2.3	2.7	2.4
M$\underline{3}$, anteroposterior diameter	2.3	2.2	....	2.2
M$\underline{3}$, greatest transverse diameter	2.1	2.0	....	2.2

a, Approximate.
* Recent skulls from Donald R. Dickey Collection.

Liodontia alexandræ (Furlong)

G. S. Miller and J. W. Gidley[3] established the genus *Liodontia* with the species *Aplodontia alexandræ* Furlong[4] as the type. If, as seems advisable, the Miocene and apparently Pliocene types are to be recognized as generically distinct from the Quaternary representatives of the family, the following characters may serve in part to distinguish *Liodontia* from *Aplodontia*.

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[1] J. W. Gidley, U. S. Geol. Surv. Prof. Paper 131-E, pp. 121-122, 1922.
[2] J. W. Gidley, *ibid.,* p. 122, 1922.
[3] See G. S. Miller and J. W. Gidley, Jour. Wash. Acad. Sci., vol. 8, p. 440, 1918.
[4] E. L. Furlong, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 397-403, 1910.

Generic characters of Liodontia—Size smaller than *Aplodontia*. Greater anteroposterior convexity to dorsal surface of cranium. Lower jaws less robust. Dental formula: $\frac{1}{1}$, $\frac{0}{0}$, $\frac{2}{1}$, $\frac{3}{3}$. Diastema between I and P$\overline{4}$ relatively short. Teeth hypsodont as in *Aplodontia*. Upper teeth with pattern similar to that in *Aplodontia*. Lower teeth of adult specimens without mesostyle on paramere. Antero-external fold in lower teeth early reduced. Enamel lakes in P $\frac{4}{4}$ retained in relatively late wear.

Revision of species—The type specimen of *L. alexandræ*, No. 11325 Univ. of Calif. Coll. Vert. Pale., is recorded from loc. 1090 (Univ. of Calif.) in the Virgin Valley beds of northwestern Nevada and is considered as Miocene in age. The cotypes, on the other hand, are recorded as having come from locality 1103 (Univ. of Calif.) in the Thousand Creek beds west of Railroad Ridge and immediately to the east of the Virgin Valley basin. The Thousand Creek deposits are regarded as Pliocene in age. An examination of this material, in the light of forms now known from the Skull Spring locality, has led the author to believe that a second species is present in the material from northwestern Nevada, represented by the Thousand Creek specimens. The upper dentitions of *Liodontia* from the two Nevada horizons are not particularly diagnostic, and for that matter differ little except in size from Recent teeth. However, in a comparison of the Thousand Creek lower jaws with a specimen from the Virgin Valley beds referred to *L. alexandræ*, differences in the character of the teeth are noted which may be regarded as of specific importance. The lower jaws from Skull Spring rather uniformly resemble the Virgin Valley specimen, with no tendency toward the characters shown by the Thousand Creek lower jaws.

In view of the distinction which ought to be made between the types from the Virgin Valley Miocene and Thousand Creek Pliocene it appears necessary to revise the description of *Liodontia alexandræ*, utilizing the characters exhibited only by the Virgin Valley specimens, namely the type No. 11325 from loc. 1090 and the referred lower jaw No. 11864 from loc. 1095, which becomes a plesiotype.

Specific characters of Liodontia alexandræ—Size larger than *Meniscomys hippodus* and smaller than *Aplodontia rufa*. P$\underline{4}$ with two strongly developed lateral styles and upper molars with prominent mesostyles. Lower jaw with protuberances below lower ends of teeth. Anteroventral margin of masseteric fossa weak. Inner wall or paramere of lower molars and P$\overline{4}$ without median style. Inner wall of lower molars crescentic with anterior and posterior angles equally developed. Antero-external fold conspicuous in lower molars of moderate wear.

The Thousand Creek material is referred to a new species, for which the name *Liodontia furlongi* is proposed. The type specimen for this species is a lower jaw, No. 11897 Univ. of Calif. Coll. from locality 1103 (Univ. of Calif.). An upper dentition No. 11898 Univ. of Calif. Coll. and an immature lower jaw No. 11909 Univ. of Calif. Coll. from the same locality are considered as paratypes.

Specific characters of Liodontia furlongi—Size similar to that of *L. alexandræ*. Mesostyles on upper teeth slightly more acute. Protuberances on lower jaw less conspicuous. Antero-ventral margin of masseteric fossa strongly developed and extends slightly farther forward. Inner wall of lower molars and $P\overline{4}$ without mesostyle in adult specimen. Very weak mesostyle on lower teeth of immature specimen. Postero-internal angle of lower teeth developed into a prominent style, and antero-internal angle of molars rounded out. Antero-external fold on lower molars prominent in immature stage, but much reduced with advanced wear.

From the above description it is seen that *L. furlongi* differs from *L. alexandræ* in acuteness of styles in upper teeth, in reduction of ventral protuberance on lower jaw, in development and position of masseteric ridge and in character of inner wall of lower teeth. *L. furlongi* approaches *Aplodontia* more closely than does *L. alexandræ* in the reduction of the ventral protuberances and in the development and position of the masseteric ridge.

Description of Skull Spring material—The material from Skull Spring representing *L. alexandræ* consists of a series of six superior dentitions, Nos. 321 to 326 inclusive, C.I.T. Coll. Vert. Pale.; five lower jaws, Nos. 327 to 331 inclusive; and a number of isolated teeth. Specimen No. 321 is more complete than the others and exhibits the shape of the cranium as well as a full grinding dentition. Complete incisors have not been preserved in any of the specimens. Lower jaw No. 327 retains the basal part of the incisor up to the point of its emergence from the alveolus.

Skull—Specimen No. 321, although small, resembles *Aplodontia* in breadth of the cranial region and in the tapering of the skull forward to the frontals. Likewise the skull becomes rather constricted in the region of the olfactory lobes. A noticeable difference exists in the slope or longitudinal profile of the back portion of the skull. In Recent species of *Aplodontia* there is a tendency for the skull to be nearly flat on top, and this character becomes pronounced with age.[1] The posterior portion of the cranium in the fossil is much depressed, giving a more convex profile than is present even in immature specimens of Recent species. As indicated by the teeth, the fossil specimen belongs to a mature individual.

In those specimens in which $P\underline{3}$ is preserved, the tooth is a simple conical column appressed against the antero-internal surface of $P\underline{4}$. The permanent $P\underline{4}$ and molars in the mature specimens are simple hypsodont teeth having evenly rounded lingual surfaces. The external surfaces of the molars have prominent mesostyles extending the vertical length of the tooth. $P\underline{4}$ is slightly longer anteroposteriorly than the molars and is characterized by two external styles.

The series of teeth of the individuals represented in the collection exhibit interesting variations in stages of wear. In No. 326 (see plate 3, figs. 4 and 4*a*) of the upper series, $Dp\underline{4}$ is in place with the anterior molars just erupting. $Dp\underline{4}$ is tending toward hypsodonty, but has three well-developed roots. The two exterior styles extending downward from the root region become pronounced toward the occlusal surface. The cusps are all conspicuous. The paracone and metacone extend ventrally beyond the styles. The protocone is a long crescentic ridge convex internally. A most interesting as well as highly important feature is the centrally located position of the protoconule(?) and metaconule(?). These cusps in the unworn permanent $P\underline{4}$ of Recent *Aplodontia* are more marginally situated. The position of the cusps in the $Dp\underline{4}$ of the Skull Spring form is almost identical with that in $P\underline{4}$ of *Meniscomys hippodus* Cope. The only difference apparently is that in No. 326 the valley folding is somewhat more accentuated than in

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[1] W. P. Taylor, Univ. Calif. Publ. Zool., vol. 17, p. 440, 1918.

Meniscomys. In No. 326 $Dp\underline{4}$ is very little worn. Some of the enamel folds are only slightly truncated, others not at all.

The stage of wear in the more mature specimens is indicated by the number of enamel lakes retained by $P\underline{4}$. Specimen No. 323 (see plate 3, fig. 3) from Skull Spring shows four lakes in $P\underline{4}$. Specimens 324 and 325 present a stage of wear similar to that of the type specimen from Virgin Valley, in which three lakes are retained. No. 322 (see plate 3, fig. 2) from Skull Spring has only one basin. Still more advanced wear is exhibited by $P\underline{4}$ in No. 321, which is without lakes. In Recent *Aplodontia* only two lakes are of sufficient depth to endure for any appreciable period in the course of attrition.

Mandible—The lower jaws of *L. alexandræ* from Skull Spring resemble in shape the mandible of *Aplodontia* but are much smaller. The marginal portion of the posterior part of the ramus has not been preserved in any of the specimens. No. 327 (plate 4, figs. 5, 5*a* and 5*b*) and No. 330 (plate 4, figs. 3, 3*a* and 3*b*) show enough of this region to indicate the direction of the condyle, the coronoid and the anterior and posterior processes of the angle. The angulation is apparently the same in Recent forms. The basal portion of the ascending ramus branches perhaps somewhat higher in the fossil jaw and is situated closer to the crowns of the teeth. The anteroventral margin of the masseteric fossa is not so robust as in Recent forms. The diastema between I and $P\overline{4}$ in No. 327 is comparatively short. No. 327 exhibits an interesting development of a series of knobs along the ventro-external surface of the jaw, corresponding in position to the lower extremities of the four teeth. A similar development is seen in lower jaw, No. 11864 Univ. Calif. Coll., from Virgin Valley, Nevada.

Three stages of wear of the teeth are represented by the series of lower jaws. The most immature specimen, No. 331 (plate 4, fig. 1), possesses a very little-worn $P\overline{4}$ and the first two molars. The premolar has two pronounced longitudinal infolds. One is formed in the anterior surface of the tooth and the other in the external surface, anterior to the median portion of the tooth. The talonid region is broad and large compared with the narrow trigonid portion. The occlusal surface of the tooth is marked by two basins. The posterior basin is well back in the heel and the anterior and larger basin is more centrally located and extends into the protoconid(?) and paraconid(?) or metaconid(?) columns. There is only the faintest trace of a median style on the internal side of the tooth. This style is rather well developed in milk and permanent premolars of Recent individuals. Furthermore, an anterior style is present in the milk tooth of Recent *Aplodontia,* giving rise to a small enamel lake between protoconid(?) and paraconid(?) with continued wear. A similar isolated lake is formed in $P\overline{4}$ by an anterior union of the protoconid(?) and paraconid(?) columns and is exhibited at a stage of moderate wear. With further attrition this lake also disappears.

$P\overline{4}$ in specimens No. 327 and No. 328 is worn to a stage where the posterior basin has been obliterated. The median lake is still present, as are likewise the two anterior folds. In No. 328 (see plate 4, figs. 4, 4*a* and 4*b*), a small groove is present just posterior to the external fold. The greatest wear is exhibited by $P\overline{4}$ in specimens No. 329 and No. 330 in which the median lake is lost. In No. 330 the anterior groove is compressed, but in No. 329 (see plate 4, fig. 2) this character is somewhat obscure and the enamel does not appear to be continuous across the front of the tooth. The inner surface of the tooth has a compound curvature anteroposteriorly, concave outward in the posterior part. This is true of the other specimens as well.

All the inferior molar teeth in the various individuals recorded from Skull Spring show a crescentic inner tooth margin which is concave lingually. There is no evidence of an inner median style characteristic of Recent forms. An absence of the style is noted also in the premolars, but a very feeble deflection occurs in P$\overline{4}$ of No. 331. A pronounced antero-external fold is present in the molars of No. 331 and diminishes farther down the tooth-crown. This fold is also conspicuous in M$\overline{3}$ of specimens No. 327 and No. 328. In Recent specimens the fold remains prominent in all the molars to a rather late stage of wear.

Relationships—*Aplodontia* (?) *asiatica*[1] differs from the Nevada and Oregon material in many respects. The median horizontal crest in the masseteric fossa dividing the areas for attachment of the *masseter medialis* and *masseter lateralis* muscles is not conspicuous in any of the lower jaws of *L. alexandræ* or of *L. furlongi*, but is traceable in many specimens of *A. rufa.* The teeth in the lower jaw described by Schlosser[2] show a stage of wear in which P$\overline{4}$, M$\overline{2}$ and M$\overline{3}$ still retain the median lake, M$\overline{1}$ does not. The antero-external fold is present on all four teeth. This fold is also present on the three teeth of an immature lower jaw No. 331 from the Skull Spring horizon and is conspicuous in teeth, not too much worn, of *A. rufa.* The external curvature of the molar teeth is not noticeably different from that in the Skull Spring material.

A.(?) *asiatica* is apparently a primitive branch from the aplodont stock which may have separated from the American group at a time when the development had reached a stage somewhere between *Meniscomys hippodus* and *Liodontia alexandræ.* If the Asiatic form occurs in association with *Hipparion richthofeni* its position in time and space obviates the possibility of origin of the Nevada forms of *Liodontia* from this type as suggested by Schlosser.

The specimen, No. 19798 Univ. Calif. Coll., from the upper Miocene Cedar Mountain beds of west-central Nevada[3] may represent Dp$\underline{4}$ of *Liodontia alexandræ* or of some closely related species. The position of the enamel lakes agrees with that in No. 326, and the divergence of the roots is not less than that in the Skull Spring Dp$\underline{4}$. In No. 326, however, P$\underline{4}$ is not shown and M$\underline{1}$ has just erupted and is extremely hypsodont. The Cedar Mountain horizon is regarded as somewhat later than the stage represented by the Skull Spring and Virgin Valley faunas.

The derivation of *Aplodontia* from *Meniscomys hippodus* has been suggested by several writers among whom may be mentioned Cope, Matthew and Gidley, Furlong, J. C. Merriam, Taylor and Schlosser. The intermediate position of *Liodontia* between *Meniscomys hippodus* and *Aplodontia rufa* has been considered by Furlong and by Taylor. The derivation of *Liodontia* from *Meniscomys hippodus* is further indicated by the characters exhibited in the milk tooth of specimen No. 326 from Skull Spring.

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[1] M. Schlosser, Palæont, Sinica, vol. 1, pp. 30-31, 1924.

[2] M. Schlosser, *op. cit.,* plate II, fig. 15, 1924.

[3] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 9, pp. 177-179, fig. 14, 1916.

Comparative Measurements

	L. alexandræ					A. rufa*
	No. 321 C.I.T.	No. 322 C.I.T.	No. 323 C.I.T.	No. 324 C.I.T.	No. 11325 Univ. Calif. Type	No. 8671
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Depth of skull between frontals and palate...	11.7	...	...	...	.....	19.3
Width of palate between $P\underline{4}$..........	4.0	4.3	4.2	...	4.5	5.1
Width of palate between $M\underline{3}$..........	3.5	...	...	...	4.5	6.0
$P\underline{3}$-$M\underline{3}$, greatest length.	11.1	11.7	...	...	*a* 12.5	17.8
$P\underline{4}$, anteroposterior diameter	3.3	3.5	4.0	4.0	*a* 4.0	4.8
$P\underline{4}$, greatest transverse diameter	3.0	3.4	3.6	3.9	4.0	5.4
$M\underline{1}$, anteroposterior diameter	2.2	2.4	2.4	2.6	2.5	3.9
$M\underline{1}$, greatest transverse diameter	3.0	2.9	3.5	3.4	3.0	4.7
$M\underline{2}$, anteroposterior diameter	2.6	2.5	2.5	2.8	2.5	3.7
$M\underline{2}$, greatest transverse diameter	2.6	2.9	3.2	3.0	3.0	4.2
$M\underline{3}$, anteroposterior diameter	2.6	2.6	...	...	*a* 3.0	4.4
$M\underline{3}$, greatest transverse diameter	2.4	2.4	...	...	.....	3.7

	L. alexandræ				A. asiatica	A. rufa* No. 8671
	No. 327 C.I.T.	No. 328 C.I.T.	No. 329 C.I.T.	No. 11864 Univ. Calif.		
Depth of ramus at $P\overline{4}$..	8.1	7.5	*a* 7.7	8.3	...	15.5
Depth of ramus at $M\overline{2}$.	7.0–8.0	8.3	*a* 7.6	8.7	6.6	12.8
Length of diastema between I and $P\overline{4}$......	(?)5.0	...	...	...	9.5	13.3
$P\overline{4}$ to $M\overline{3}$, greatest length..............	11.0	11.0	11.4	11.4	10.5	16.4
$P\overline{4}$, anteroposterior diameter	3.2	3.3	3.4	3.2	3.5–4.5	4.4
$P\overline{4}$, greatest transverse diameter	2.3	2.4	2.5	2.2	.....	3.9
$M\overline{1}$, anteroposterior diameter	2.6	2.5	2.7	2.5	.....	3.7
$M\overline{1}$, greatest transverse diameter	2.3	2.3	2.3	2.2	.....	3.7
$M\overline{2}$, anteroposterior diameter	2.6	2.6	2.8	2.6	.....	3.7
$M\overline{2}$, greatest transverse diameter	2.2	2.1	2.3	2.0	.....	3.2
$M\overline{3}$, anteroposterior diameter	2.7	2.6	2.8	2.7	.....	4.0
$M\overline{3}$, greatest transverse diameter	1.9	1.8	1.8	1.8	.....	3.0

a, Approximate.
* Recent skulls from Donald R. Dickey Collection.

Mylagaulus, cf. lævis Matthew

This aberrant rodent in the Skull Spring fauna is represented in the collection of the California Institute by five skulls or portions of skulls, four lower jaws, approximately thirty isolated teeth, the distal part of a humerus, and the proximal end of a femur. The most complete skull, No. 68 C. I. T. Coll. Vert. Pale. (plate 5, figs. 1, 1*a*, and 1*b*), was worked out of a nodule and is fairly well preserved. The right zygoma and tooth series were exposed and weathered away. P4, M2 and M3 are present in the left maxillary. No. 69 is less completely preserved, but a portion of the left ramus of the mandible is still attached to the skull. M2 and M3 are preserved on both sides with P4 only on the left. Nos. 365, 366 and 367 are fragments of skulls with teeth. No. 366 (plate 4, fig. 6) is an immature individual with an unworn P4 and the first two molars present. The three isolated lower jaws, Nos. 70 (plate 5, figs. 2, 2*a*, and 2*b*), 368 (plate 5, figs. 4, 4*a*, and 4*b*), and 369 (plate 5, figs. 3, 3*a*, and 3*b*), are fairly well preserved except for their posterior portions and incisors.

Specimen No. 68 from Skull Spring approaches more closely *Mylagaulus lœvis* of the lower Snake Creek beds than to any other species so far described. The Oregon specimen is slightly larger than the Snake Creek *M. lœvis* and is distinctly larger than the type from the Pawnee Creek beds. The curvature of the zygomatic arch is very similar to that in No. 17576 of the Amer. Mus. Coll. from the lower Snake Creek horizon. No. 68 differs in this respect very decidedly from skulls of *M. vetus, Ceratogaulus rhinocerus* and *Epigaulus hatcheri,* whose zygomatic arches are not so much expanded antero-laterally. No. 68 possesses a more slender arch than either the Snake Creek *M. lœvis* or the type of *C. rhinocerus,* and the post-orbital process of the zygoma is more prominently developed. The post-orbital process of the frontal and the superior orbital notch are fully as conspicuous in No. 68 as in Amer. Mus. No. 17576. The temporal crests, while farther apart anteriorly behind the post-orbital processes than in Amer. Mus. No. 17576, approach each other more closely posteriorly than in the latter. The crests are much more widely separated in the horned forms, *C. rhinocerus* and *E. hatcheri.* A conspicuous difference between No. 68 and the Snake Creek *M. lœvis* is in the slope of the occiput. In No. 68 the surface slopes more gradually downward and backward from the dorsal rim. In this character No. 68 differs also from Amer. Mus. No. 9456 (skull type) of *C. rhinocerus.* However, No. 69, a more fragmentary skull from Skull Spring, shows a steeper occiput, but on the basis of the teeth appears to be specifically identical with No. 68.

The fourth upper premolars from Skull Spring are concave externally in vertical profile and have on their sides an antero-external and an antero-internal groove which usually become more conspicuous with advanced wear, particularly the internal groove. These teeth show a minimum of five lakes corresponding to the five basins in *Meniscomys hippodus* and the milk tooth of *Liodontia alexandrœ.* The maximum number of lakes occurring at one time in any of the specimens in the collection is seven, although apparently this number may be increased to eight or nine. The molars are small and simple, and only the second and third are present in mature individuals.

The three lower jaws, Nos. 70, 368 and 369, are of approximately the same size but vary somewhat in thickness. No. 70 is the heaviest jaw and in thickness approaches the type of *M. monodon* but is not so deep. *M. vetus,* although close in size to the lower jaw, No. 70, is somewhat more slender, in which respect it may resemble No. 368. The fourth premolars in the Skull Spring specimens are, however, larger than in the type of *M. vetus*. *M. paniensis* and *M. novellus* are distinctly smaller forms, as are also *M. pristinus* and *M. proximus*.

The lower fourth premolars from Skull Spring are large teeth, which in cross-section become long and narrow with advanced wear. In little-worn teeth, grooves are conspicuous on the sides, particularly on the antero-external and postero-internal surfaces. These grooves may not persist throughout the length of the tooth. The enamel lakes on the crown are arranged obliquely along the inner and outer walls, the elongation being antero-external to the long diameter of the tooth. The pattern is noticeably uniform throughout the specimens in the collection. The number of lakes is usually six and occasionally seven. The seventh lake may possibly be produced through a division of the second of the three internal lakes. The corresponding tooth in the types of *Mylagaulus vetus*, *M. paniensis* and *M. pristinus* has five lakes, and in *Mesogaulus ballensis* four are present. On the other hand, *Mylagaulus monodon* has seven major lakes and a referred specimen has two minor lakes in addition.

Relationships—The derivation of *Mylagaulus* from *Meniscomys* was first discussed by Cope,[1] later by Riggs,[2] and still later by Matthew.[3] A consideration of the enamel pattern in P4̲ of an immature mylagaulid, No. 366 from Skull Spring, further suggests this relationship. The tooth is practically unworn and shows, as does Dp4̲ of *Liodontia alexandræ* from Skull Spring, a close approximation in arrangement of cusps and basins to that in P4̲ of *Meniscomys hippodus*.

The Skull Spring specimen, No. 68, approaches rather closely skulls of Recent *Aplodontia rufa* in size. There is a striking similarity in many characters between *Mylagaulus* and *Aplodontia*. This has been pointed out by Gidley[4] in a discussion of the relationships of *Epigaulus* and by Matthew[5] in a statement concerning *M. lævis*. A similar appearance is most noticeable in the dorso-ventral compression of the skull, in lateral expansion of the zygomatic arches and the occipital region of the skull and in the general proportions of the lower jaws. The outstanding differences lie in the heaviness of the zygoma in the mylagaulid, the shape of the brain case, the presence of post-orbital processes and ridges, the less-deflected angle of the lower jaw and in the character of the teeth.

Apparently the greatest divergence between *Aplodontia* and *Mylagaulus* exists in their separate dental development. The dentition in *Aplodontia* has become extremely hypsodont, the external styles are emphasized, the enamel lakes reduced and the several teeth in the jaws tend toward a uniform pattern with no very great difference in size. In the mylagaulid dentition on the other hand, the fourth premolar is developed at the expense of all the other cheek-teeth, the fossettes are emphasized and the external styles are reduced at an early stage. Hypsodonty is developed to a varying degree in the different teeth of the series, best shown in the enlarged premolar and least in the first molar.

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[1] E. D. Cope, U. S. Geol. and Geog. Surv. Terrs., vol. 4, pp. 384-385, 1878.

[2] E. S. Riggs, Field Columbian Mus. Publ. 34, Geol. Ser., vol. 1, pp. 183-186, 1899.

[3] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 81-84, 1924.

[4] J. W. Gidley, Proc. U. S. Nat. Mus., vol. 32, pp. 628-635, 1907.

[5] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 78-81, 1924.

Comparative Measurements

	M., cf. lævis	
	No. 68 C.I.T.	No. 69 C.I.T.
	mm.	*mm.*
Greatest width from median line of skull to outer surface of zygoma	34.5	......
Distance from occipital crest to naso-frontal suture	27.0	*a*30.0
Distance from anterior surface of $P\underline{4}$ to tip of condyle	48.5	*a*41.2
Width of palate between $P\underline{4}$	*a*5.0	*a*5.0
Length of superior grinders, $P\underline{4}$, $M\underline{2}$ and $M\underline{3}$	16.8	*a*15.5
$P\underline{4}$, anteroposterior diameter at alveolar border	*a*9.0	*a*9.0
$P\underline{4}$, greatest transverse diameter at alveolar border	6.3	5.9
$M\underline{2}$, anteroposterior diameter	3.5	3.6
$M\underline{2}$, greatest transverse diameter	4.3	4.2
$M\underline{3}$, anteroposterior diameter	3.0	2.8
$M\underline{3}$, greatest transverse diameter	3.7	3.2

	M., cf. lævis			M. vetus	M. monodon
	No. 70 C.I.T.	No. 368 C.I.T.	No. 369 C.I.T.	No. 18905 Type*	No. 8327 Type*
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
Depth of jaw at posterior end of $P\overline{4}$	*a*14.5	*a*13.2	14.7	14.6	*a*16.4
Thickness of jaw at anterior end of masseteric area	*a*10.2	*a*6.4	*a*9.0	6.3	8.3
Length of inferior grinders, $P\overline{4}$, $M\overline{2}$ and $M\overline{3}$	*a*17.7	17.8	16.8	....	....
$P\overline{4}$, anteroposterior diameter at alveolar border	9.5	9.9	9.8	7.9	*a*9.8
$P\overline{4}$, greatest transverse diameter at alveolar border	*a*5.0	4.4	4.8	4.3	*a*6.0
$M\overline{2}$, anteroposterior diameter	....	3.8	3.7	....	....
$M\overline{2}$, greatest transverse diameter	....	3.5	3.4	....	....
$M\overline{3}$, anteroposterior diameter	....	3.3	3.6	....	....
$M\overline{3}$, greatest transverse diameter	....	2.4	2.3	....	....

a, approximate. * Amer. Mus. Coll.

Diprionomys ? oregonensis n. sp.

Holotype—No. 371 C. I. T. Coll. Vert. Pale., a fragmentary skull and lower jaw, from locality 57 near Skull Spring, Malheur County, Oregon.

Paratype—No. 370, a skull from the same locality.

Specific characters—Skull near size of *Heteromys desmarestianus psakastus*. Cranium broader and slightly longer. Interparietal larger. Diastema between I and $P\underline{4}$ and that between I and $P\overline{4}$ approximately as in *H. d. psakastus*. Teeth slightly larger than in *Heteromys*. Incisors without grooves. Upper and lower cheek-teeth three-rooted, brachydont and cleft nearly as in *Perognathus*. Antero-internal fold on posterior column of $P\underline{4}$ curves outward. Anterior column of $P\overline{4}$ divided by fold from posterior surface in moderate wear. Transverse ridges on upper molars irregular. Lower molars oval with transverse ridges uniting first near middle of teeth. Third molars smaller than second molars.

Material—The Skull Spring locality has produced a remarkable group of specimens representing pocket mice. The collection includes four skulls and a lower jaw. The skull of the type, No. 371, is only partially preserved, but shows the shape of the cranium and has a complete left grinding dentition. The lower jaw of the type is the right ramus which has all of the teeth preserved. The jaw was found in place in the same nodule with the skull, but had weathered away below the roots of the teeth. The paratype, No. 370, is in a better state of preservation than other specimens. The skull is not complete behind the cheek-teeth, but the rostrum retains both incisors. The left grinding series is in perfect condition. Skull No. 372 retains the cranium but is incomplete anterior to $P\underline{4}$. The left cheek-teeth and most of the right are present. In a poorly preserved skull of an old individual, No. 373, the major portion of the dentition is present, including the incisors.

Skull—In size the specimens are close to *Heteromys,* being somewhat larger than *Liomys* and much larger than species of *Perognathus.* The cranium is long and broad, more so than in *Heteromys,* and perhaps more compressed dorsoventrally. The specimens do not exhibit a disproportionately large inflation of the cranium, characteristic of *Dipodomys* and *Microdipodops.* The enlargement seen in the latter genera has altered the shape of the parietals and reduced the size of the interparietal considerably. In *D.*(?) *oregonensis* the parietals are apparently similar to those in *Liomys* or *Heteromys.* The interparietal is actually larger than in these pocket mice. The rostrum is long and moderately slender with nasals protruding beyond the incisors as in other pocket mice. The rostral region is not so reduced as in the kangaroo-rats, nor is the palate between the cheek-teeth relatively as wide. The diastema between the incisors and $P\underline{4}$ in Nos. 370 and 373 compares favorably in length with that in *Heteromys,* being longer than the average of *Liomys.*

Upper dentition—The cheek-teeth in *D.* ? *oregonensis* are perhaps a little larger than in *Heteromys,* but are much more brachydont and three rooted, resembling *Perognathus* in these characters. The separate teeth are approximately three-quarters as long as they are wide and decrease in size posteriorly, but not so rapidly as in *Liomys* and *Perognathus.* The pattern resembles to a marked degree that seen in *Perognathus* but is somewhat simpler and suggestive of *Liomys* in this respect.

The upper dentitions present in the collection exhibit varying stages of wear. No. 370 with least wear possesses the most complicated pattern on the occlusal surface of individual teeth. The anterior column of $P\underline{4}$ in this specimen is simple and oval in shape. The posterior column is somewhat crescentic in shape and has on its anterior concave surface two re-entrant folds, indicating a three-cusped origin for this column or ridge. The external of the two re-entrant folds is approached by a weak postero-external fold on the convex surface of the column, emphasizing the three-fold division of the ridge. The internal of the two anterior folds is much more deeply impressed and curves outward, nearly parallel to the postero-internal surface of the column. The corresponding fold in *Heteromys* and *Liomys* curves inwardly; it is not emphasized in *Perognathus.* The crowns of the first and second molars show, as in *Perognathus* and in young specimens of *Liomys,* evidence of a development from a six-cusped tooth. The transverse fold in these two teeth is deeply impressed, nearly as much as in *Perognathus,* but more so than in *Liomys* or *Heteromys*. The posterior ridge of the third molar is reduced transversely and may have been single-cusped. The ridges are connected internally in M$\underline{2}$ and M$\underline{3}$ at the stage of wear reached in these teeth.

The wear in No. 371 has increased the crown surface of the anterior column of P$\underline{4}$, which almost touches the surface of the posterior column. The infoldings on the anterior surface of the latter column are much reduced. The two ridges in M$\underline{1}$ are connected internally as in the posterior molars. The enamel on the ridges of the molars is still slightly irregular, but the median valleys are very shallow.

In No. 372 wear has obliterated the valleys of the molars, except for an external notch in the crown. P$\underline{4}$ is a very simple type of tooth, but the two columns are still distinct. The crown heights in this specimen are low.

The greatest wear has been reached in No. 373, in which the two columns of P$\underline{4}$ have united. M$\underline{1}$ is oval in shape with no trace of an external notch. Apparently M$\underline{2}$ and M$\underline{3}$ have been worn down to the roots.

The upper incisors in Nos. 370 and 373 are of approximately the size seen in *Heteromys*. These teeth are without grooves, in which respect *D.* ? *oregonensis* differs from *Perognathus, Dipodomys* and *Microdipodops*, and is like *Heteromys* and *Liomys*.

Lower dentition—The lower grinding teeth of No. 371 are also brachydont and show a stage of wear in which the transverse folds are about to be obliterated. Unlike the upper teeth, the ridges unite first near their middle, but persist longest on the inner margin.

The two columns of P$\overline{4}$ are of nearly equal size, the posterior being slightly wider than the anterior. The folding has been slightly more pronounced on the inner side of this tooth. The inner fold upon reaching the center of the tooth branches forward across the middle of the anterior column almost to its anterior surface, thus dividing the column into two equal parts. The forwardly directed fold is shallow, but at an earlier stage in the history of this tooth must have divided the column into two cusps. The external fold or notch has only recently become separated from the inner. The tooth was probably four-cusped at an early stage of wear, but the depth of folding differs slightly from that in *Perognathus* and *Liomys*.

The lower molar teeth are nearly oval in shape and are divided by folds from both the inner and outer walls. In M$\overline{1}$ the transverse ridges are still separated; however, the ridges of the remaining two molars are connected. A small pit is present in the anterior part of the occlusal surface of M$\overline{3}$.

The lower incisors differ little from those in *Heteromys* other than being perhaps slightly broader anteriorly.

Comparison—Among Recent forms *Diprionomys* ? *oregonensis* appears to resemble most closely *Heteromys* in size and in proportions. In character of the dentition the species from Skull Spring lies between *Perognathus* and *Liomys*. The fossil shows only a very remote resemblance to such forms as *Dipodomys* and *Microdipodops*.

The Skull Spring form is much more brachydont than the later Tertiary species of *Diprionomys*. The type species *D. parvus* Kellogg[1] from the Thousand Creek beds of northwestern Nevada, in addition to being more hypsodont is much smaller than the Oregon form, but the pattern of P$\overline{4}$ may not differ greatly from that in the latter. *D. magnus* Kellogg,[2] from the same locality in the Thousand Creek beds, has apparently a larger $P\overline{4}$ and smaller molars than *D.* ? *oregonensis.* The pattern of $P\overline{4}$ is also different and the lower incisor is relatively broader and shorter anteroposteriorly.

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[1] Louise Kellogg, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 433-434, 1910.

[2] Louise Kellogg, *ibid.*, pp. 434-435, 1910.

The species of *Diprionomys* from the Fish Lake Valley beds of west-central Nevada are smaller types with more hypsodont teeth. *D. tertius* Hall[1] is actually smaller than *D. parvus. D. quartus* Hall[2] is between *D. parvus* and *D. magnus* in size, and shows certain points of resemblance to *Dipodomys* and to *Liomys.*

The pattern of the lower teeth of *D.* ? *oregonensis* resembles to a marked degree that seen in the illustration of *Peridiomys rusticus* described by Matthew[3] from the lower Snake Creek beds of Nebraska. Lower jaw No. 371 of *D.* ? *oregonensis* shows relatively greater wear than the type of *P. rusticus,* but may be in reality more brachydont, as indicated by a comparison with the illustrations and with a cast of the type. The alveolar length of the lower tooth-series of *P. rusticus* is considerably greater than that of *D.* ? *oregonensis* and the length of the diastema between I and $P\overline{4}$ is relatively shorter. Although the two types exhibit considerable disparity in size, they may ultimately prove to be congeneric. The similarity in pattern of the teeth between *D.* ? *oregonensis* and *P. rusticus* is greater than that between the Oregon form and any previously described species of *Diprionomys.*

Perognathus furlongi Gazin[4] from Upper Miocene beds in southern California is a smaller form showing an unmistakable relationship to the Recent species of that genus. The rostrum is deep dorso-ventrally but is much narrower than in *Diprionomys* ? *oregonensis.* The cheek-teeth are more strikingly perognathoid, and in addition the incisors are grooved as in Recent forms.

Phylogenetic history—The heteromyid species recorded in the Skull Spring fauna is the earliest form which may be tentatively referred to the genus *Diprionomys.* Both *D.* ? *oregonensis* and *Peridiomys rusticus* appear to belong to approximately the same time stage in the Miocene. The brachydont dentition and the prominence of the folds in the teeth of these Miocene forms suggest that the brachydont, cuspate character of the teeth in *Perognathus* is a more primitive type among Recent forms. The increased hypsodonty seen in specimens from the upper Miocene Fish Lake Valley beds and from the Pliocene Thousand Creek deposits indicates a more progressive development leading perhaps toward forms such as *Dipodomys.*

The ancestry of the living genera is still uncertain, but the broad range of species in the *Diprionomys* group may include forms from which one or more of the Recent groups have developed. The group probably does not contain the ancestor of *Perognathus* as the occurrence of *P. furlongi* in beds of Upper Miocene age in Cuyama Valley precludes a derivation of this form from *Diprionomys.*

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[1] E. R. Hall, Univ. Calif. Publ., Bull. Dept. Geol., vol. 19, pp. 297-298, figs. 2-4, 1930.

[2] E. R. Hall, *ibid.,* pp. 298-301, figs. 5-8, 1930.

[3] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, p. 85, 1924.

[4] C. L. Gazin, Carnegie Inst. Wash. Pub. No. 404, pp. 66-67, 1930.

Comparative Measurements

	D. ? oregonensis	
	No. 371 C.I.T.	No. 370 C.I.T.
	mm.	*mm.*
Distance from naso-frontal suture to posterior end of skull	26.0	....
Greatest transverse width of cranium	15.3	....
Depth of skull between palate and dorsal surface	*a*8.3	*a*8.5
Width of palate between P$\underline{4}$	*a*2.4	*a*2.4
Length of diastema between I and P$\underline{4}$	....	*a*9.4
Alveolar length, P$\underline{4}$ to M$\underline{3}$ inclusive	6.1	5.5
I, anteroposterior diameter	....	1.5–1.7
I, greatest transverse diameter	....	1.0
P$\underline{4}$, anteroposterior diameter (occlusal surface)	1.6	1.3
P$\underline{4}$, greatest transverse diameter	2.0	1.7
M$\underline{1}$, anteroposterior diameter	1.3	1.2
M$\underline{1}$, greatest transverse diameter	1.8	1.6
M$\underline{2}$, anteroposterior diameter	1.2	1.1
M$\underline{2}$, greatest transverse diameter	1.7	1.6
M$\underline{3}$, anteroposterior diameter	1.2	1.1
M$\underline{3}$, greatest transverse diameter	1.6	1.3

	D. ? oregonensis No. 371 C.I.T.	P. rusticus No. 18894*
Length of diastema between I and P$\overline{4}$	*a*4.5	*a*4.3
Alveolar length of P$\overline{4}$ to M$\overline{3}$ inclusive	5.4	6.9
I, anteroposterior diameter	1.5	....
I, greatest transverse diameter	1.0	....
P$\overline{4}$, anteroposterior diameter (occlusal surface)	1.3	*a*1.6
P$\overline{4}$, greatest transverse diameter	1.5	*a*1.9
M$\overline{1}$, anteroposterior diameter	1.2	*a*1.5
M$\overline{1}$, greatest transverse diameter	1.7	*a*2.2
M$\overline{2}$, anteroposterior diameter	1.3	*a*1.5
M$\overline{2}$, greatest transverse diameter	1.7	*a*2.1
M$\overline{3}$, anteroposterior diameter	1.2	....
M$\overline{3}$, greatest transverse diameter	1.4	....

a, approximate. * Amer. Mus. Coll. (cast)

PERISSODACTYLA

Hypohippus sp.

Three upper teeth, Nos. 342, 343 and 344 C. I. T. Coll. Vert. Pale., and a lower jaw fragment, No. 341 C. I. T. Coll. Vert. Pale., with P$\underline{3}$(?) and P$\underline{4}$(?) comprise the better preserved portion of the material which has been recognized as belonging to the genus *Hypohippus*.

In the upper teeth the transverse lophs are smooth, compressed anteroposteriorly and are united with the ectoloph. The protocone and hypocone are of equal size. The crown in No. 342 (fig. 9*a*) is wide transversely in comparison to its anteroposterior diameter. This tooth is worn to a stage where the hypostyle is approaching a union with the metaloph. No. 344 (fig. 9*b*) is relatively long anteroposteriorly and is only slightly worn.

The two lower teeth in specimen No. 341 (fig. 9*c*) show an early stage of wear. The teeth are high crowned and show a pronounced cingulum on the labial side, which terminates posteriorly in a low cusp on the side of the entoconid. The metaconid-metastylid column is slightly notched on the lingual surface near the summit and the posterior portion of the column is compressed transversely, forming a ridge down the flank of the cusp. Furthermore, this column appears to be the posterior termination of the protoconid crescent, having a less direct union with the hypoconid crescent, which in turn terminates in the entoconid. There is no indication of an internal cusp between the metastylid and entoconid.

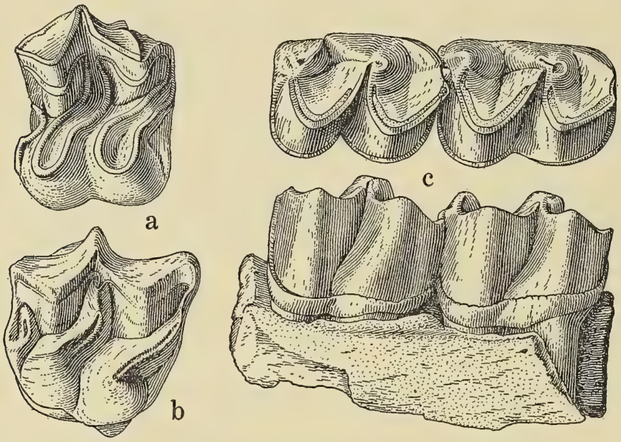

FIG. 9, *a, b,* and *c*—*Hypohippus,* sp. *a,* Right upper cheek-tooth, No. 342 C.I.T. Coll., occlusal view; *b,* right upper cheek-tooth, No. 344 C.I.T. Coll., occlusal view; *c,* lower cheek-teeth, No. 341 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

The Skull Spring *Hypohippus* resembles *H. osborni* Gidley[1] in pattern and height of crown but is closer to *H. equinus* (Scott)[2] in size. The species is not nearly so large as *H. (D.) nevadensis* Merriam[3] which occurs in the Cedar Mountain[4] and Fish Lake Valley[5] faunas of Nevada. The lower teeth in No. 341 resemble the teeth in the lower jaw from Virgin Valley[6] in many respects, but lack the small exterior cusp between the metastylid and entoconid. The Skull Spring species is perhaps nearer the Virgin Valley form than to any other type which has been described. Were more complete material available from either Virgin Valley or Skull Spring this form might be shown to be specifically distinct from both *H. equinus* and *H. osborni* of the Great Plains region.

[1] J. W. Gidley, Bull. Amer. Mus. Nat. Hist., vol. 23, pp. 930-931, 1907; H. F. Osborn, Mem. Amer. Mus. Nat. Hist., vol. 2, pt. 1, p. 207, 1918.

[2] W. B. Scott, Trans. Amer. Philos. Soc. (n.s.), vol. 18, pp. 94-122, 1894; H. F. Osborn, *ibid.*, pp. 203, 206, 1918.

[3] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, pp. 419-427, 1913.

[4] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 9, pp. 182-186, 1916.

[5] C. Stock, Univ. Calif. Publ., Bull. Dept. Geol., vol. 16, pp. 61-68, 1926.

[6] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, p. 258, fig. 28, 1911.

Comparative Measurements

	Antero-posterior diameter	Greatest transverse diameter
	mm.	*mm.*
Upper molar or premolar, No. 342........	*a*23.0	26.3
Upper molar or premolar, No. 343........	*a*23.4	*a*29.0
Upper molar or premolar, No. 344........	25.7	*a*25.9
$P\overline{3}$, No. 341..........................	23.2	15.7
$P\overline{4}$, No. 341..........................	22.9	16.3

a, approximate.

Parahippus, near coloradensis Gidley

Two upper molars, Nos. 345 and 347 C.I.T. Coll. Vert. Pale., and a lower premolar (?), No. 346, are the only specimens which can be assigned with any assurance to *Parahippus.*

No. 345 (fig. 10*a*) is a well-preserved upper tooth in early wear. The crown is high with external ribs on the paracone and metacone. No. 347 (fig. 10*b*) is also in early wear but is not so well preserved, the ectoloph being partially damaged. A noticeable feature in both teeth is the marked elevation of the protoconule. The crochet is much better developed in No. 345, and a slight plication is also present on the opposite side of the metaloph. In the latter specimen the hypostyle is large with central basin, and shows a tendency to unite with the ectoloph earlier than with the metaloph. In No. 347 a portion of the cingulum is developed on the anterior side of the tooth; this appears to have been broken away in No. 345. Furthermore, a small cusp or portion of the cingulum is present between the protocone and hypocone in No. 347. This is not present in No. 345.

The external side of the lower tooth is fairly high crowned and exhibits a rugose surface. The metaconid and metastylid are distinctly separate for nearly half the height of the crown. The cingulum is conspicuous only on the anterior and posterior ends of the tooth, the posterior end terminating in a well-developed hypoconulid. A very small cusp is present between the protoconid and hypoconid.

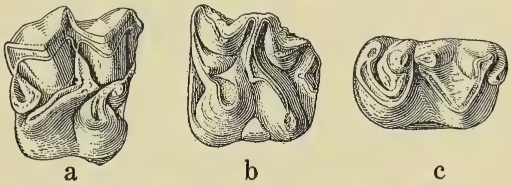

FIG. 10, *a, b,* and *c*—*Parahippus,* near *coloradensis* Gidley. *a,* Right upper cheek-tooth, No. 345 C.I.T. Coll., occlusal view; *b,* left upper cheek-tooth, No. 347 C.I.T. Coll., occlusal view; *c,* left lower cheek-tooth, No. 346 C.I.T. Coll., occlusal view; x 1.0. Skull Spring Miocene, Oregon.

The Skull Spring form is near *Parahippus coloradensis* Gidley[1] in size, height of crown and external ribbing on paracone and metacone. It differs perhaps from the latter species in simplicity of pattern and prominence of protoconule.

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[1] J. W. Gidley, Bull. Amer. Mus. Nat. Hist., vol. 23, p. 932, 1907; H. F. Osborn, Mem. Amer. Mus. Nat. Hist., vol. 2., pt. 1, pp. 93-94, 1918.

In *P. pawniensis* Gidley[1] the teeth are apparently shorter crowned and there is a greater tendency for the hypostyle to unite with the metaloph than in No. 345. The external ribs on the paracone and metacone in *P. pawniensis* are only faintly indicated, while those in No. 345 are not particularly heavy.

The Skull Spring material differs from teeth of *P. avus* in smaller size and perhaps in degree of hypsodonty. Also there is no sign of cement on any of the teeth. Lower tooth, No. 346, is approximately the same length as lower teeth from the Virgin Valley beds compared to *P. avus*, but is narrower and lower crowned. However, additional fragmentary lower teeth from Skull Spring indicate somewhat larger sizes.

P. brevidens (Marsh)[2] from the Mascall has relatively large and heavily cemented teeth. Nevertheless, Nos. 345 and 347 resemble this species in many respects as in shape of the hypostyle and protocone, and also in the ribbing of the paracone and metacone. The metaloph in *P. brevidens* tends to be more crenulate than in the Skull Spring form.

It is noteworthy that the form occurring at Skull Spring does not appear to be referable to either *P. brevidens* or *P. avus* from the Mascall.

Comparative Measurements

	Antero-posterior diameter	Greatest transverse diameter	Height of paracone	Height of hypoconid
	mm.	*mm.*	*mm.*	*mm.*
Upper molar, No. 345	17.8	21.1	12.6	...
Lower premolar (?), No. 346	19.8	11.5	....	9.6

Merychippus isonesus (Cope)

This species is represented in the collection by a maxillary fragment, No. 337 C.I.T. Coll. Vert. Pale., with $P\underline{4}$(?) and $M\underline{1}$(?), a fragment of a mandible, No. 340 C.I.T. Coll. Vert. Pale., with $P\overline{2}$ to $M\overline{3}$ inclusive, and a large number of isolated teeth. There are also several toe bones and tarsal and carpal elements which are referred to this form.

The upper teeth are long crowned[3] and usually heavily cemented. The external styles are prominent, the mesostyle tending to be compressed anteroposteriorly. The fossettes are large and open in early wear as in the type specimen.[4] The crenulation of the enamel walls of the fossettes is well developed in a moderately early stage of wear, but much simplified as the crown is shortened. The hypocone is united with the metaloph in very early wear, but retains a relatively narrow isthmus until slightly before the stage is reached in which the protocone is united with the protoloph. The union of the protocone takes place in fairly well worn teeth.

Specimen No. 337 (fig. 11*a*) from Skull Spring resembles very closely $P\underline{4}$ and $M\underline{1}$ of the type, No. 8175 Amer. Mus. Cope Coll. The prefossette and postfossette in $P\underline{4}$ (?) are open and separated by only a thin plate of

[1] J. W. Gidley, *ibid.*, p. 932, 1907; H. F. Osborn, *ibid.*, pp. 92-93, 1918.

[2] H. F. Osborn, *ibid.*, pp. 89-90, 1918.

[3] Several less hypsodent teeth in the collection, showing relatively little wear, may indicate the presence in the fauna of a second species of *Merychippus*.

[4] H. F. Osborn, Mem. Amer. Mus. Nat. Hist., vol. 2, pt. 1, p. 102, fig. 75, 1918.

enamel (metaloph). The protoconule is just in contact with a projection from the metaloph in the vicinity of the pli caballin. In the postfossette the pli hypostyle is very conspicuous. The protocone is isolated, but develops a long projection toward the protoconule. The hypocone is connected with the metaconule by a rather long and narrow isthmus. M1(?) is similar to P4(?) in general appearance. However, the fossettes are closed and the plications on the intervening portion of the metaloph are prominent. The pli caballin and pli protoconule are well developed and the protocone is more nearly oval than in P4(?).

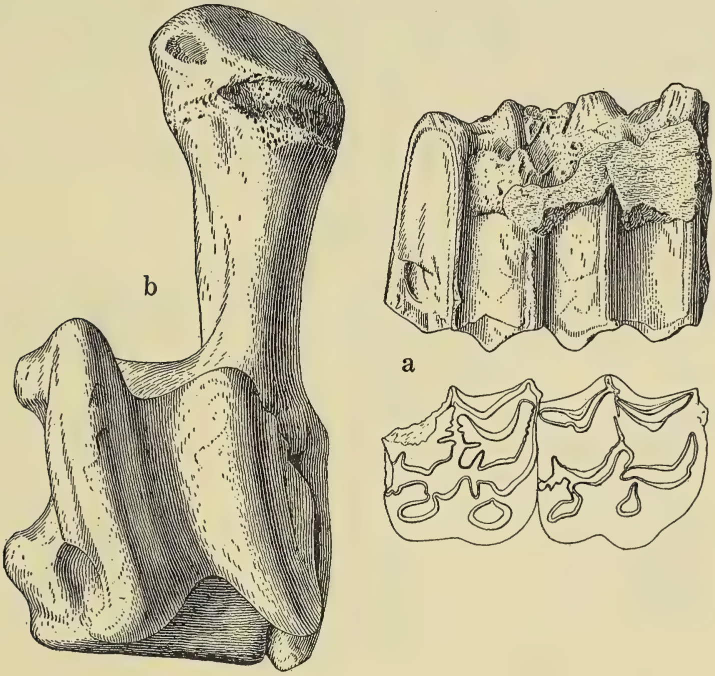

FIG. 11, *a* and *b*—***Merychippus isonesus*** (Cope). *a*, P4(?) and M1(?), No. 337 C.I.T. Coll., lateral and occlusal views; *b*, astragalus and calcaneum, No. 459 C.I.T. Coll., anterior view; x 1.0. Skull Spring Miocene, Oregon.

The lower teeth are long crowned and the amount of cement which has been deposited is variable. The protoconid and hypoconid are evenly rounded and the external median fold between these cusps is deeply impressed in moderate wear. The groove between the metaconid and metastylid is well defined for a considerable portion of the length of crown. The postero-internal basin or fold is usually not so simple as the fold between the parastylid and metaconid, the enamel frequently having two plications between the metastylid and entoconid.

The lower teeth of specimen No. 340 (fig. 12) are well worn and the enamel folding on the lingual side has been reduced to a series of notches and shallow grooves. The external fold still penetrates the greater part of the tooth width in all of the crowns. These teeth exhibit a fair covering of cement.

The teeth in this collection seem closer in structure and in stage of development to *Merychippus isonesus* from the Mascall formation in east-central Oregon than to any other species figured by Osborn.[1] The teeth in No. 337 are strikingly like the corresponding teeth in the type collected by Wortman, suggesting a contemporaneity of the Skull Spring and Mascall faunas.

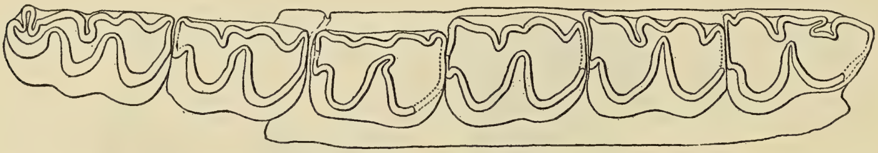

FIG. 12—*Merychippus isonesus* (Cope). P$\overline{2}$ to M$\overline{3}$ incl., No. 340 C.I.T. Coll., occlusal view; x 1.0. Skull Spring Miocene, Oregon.

Measurements

	Antero-posterior diameter	Greatest transverse diameter	Approximate height of crown
	mm.	*mm.*	*mm.*
P$\underline{2}$, No. 338...........	26.5	19.6	20.0
P$\underline{4}$ (?), No. 337........	21.9	21.4	28.0
M$\underline{1}$ (?), No. 337.......	*a* 20.6	20.7	26.0
M$\underline{3}$, No. 339..........	20.4	19.1	21.0
P$\overline{2}$-M$\overline{3}$, No. 340........	112.3	....	....
P$\overline{2}$, No. 340...........	18.6	12.2	8.0
P$\overline{3}$, No. 340...........	17.8	13.3	9.0
P$\overline{4}$, No. 340...........	18.1	13.4	11.0
M$\overline{1}$, No. 340...........	17.0	12.5	9.0
M$\overline{2}$, No. 340...........	17.1	11.9	10.0
M$\overline{3}$, No. 340...........	21.0	10.5	13.0

a, approximate.

Rhinocerotid sp.

Fragments of bones and teeth which have been recognized as belonging to the Rhinocerotidæ are unfortunately not sufficiently complete to permit generic identification. The material consists of tarsal and carpal elements, ungual phalanges, the distal end of a tibia and fragments of teeth. The latter indicate a fairly hypsodont form.

Chalicothere ? sp.

An incomplete lower tooth, No. 348 (fig. 13), possibly represents a chalicothere in the Skull Spring fauna. The tooth is well worn and brachydont with a cingulum conspicuous on the posterior end and between the protoconid and hypoconid.

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[1] H. F. Osborn, *ibid.*, pp. 98-126, 1918.

Measurements

Anteroposterior diameter of lower tooth, No. 348	30.-35. *mm.*
Transverse diameter of lower tooth, No. 348	16.5

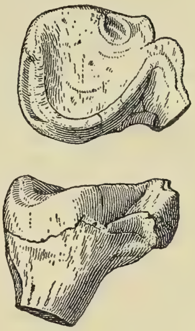

FIG. 13—Chalicothere ? sp. Lower tooth fragment, No. 348 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

ARTIODACTYLA

Platygonus ? sp.

A second upper molar, No. 381 C.I.T. Coll. Vert. Pale. (fig. 14), in the collection belongs apparently to a large suilline type. The tooth is of approximately the same size and appearance as M$\underline{2}$ in the type of *Platygonus texanus* Gidley [1] from the Pliocene of Texas. The molar is nearly rectangular with anteroposterior and transverse diameters approximately equal. The four large cusps are little worn and are surrounded by a heavy cingulum. The enamel is very rugose, particularly on the inner cusps. The latter tubercles are not so simple and conical as the outer pair but are of pyramidal shape.

The genus *Platygonus* has been recorded heretofore principally from the Pliocene and Pleistocene, and the recognition of this form in the Miocene fauna of Skull Spring remains an open question for want of more complete material.

Measurements

Anteroposterior diameter	21.7 *mm.*
Transverse diameter	*a*21.5

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a, approximate.

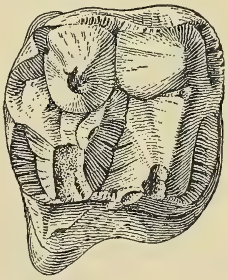

FIG. 14—*Platygonus* ? sp. M$\underline{2}$, No. 381 C.I.T. Coll., occlusal view; x 1.33. Skull Spring Miocene, Oregon.

Ticholeptus ? sp.

The recognition of oreodonts in the assemblage is based on isolated teeth. A definite generic identification on the basis of the fragmentary material now available is not trustworthy, but certain characters exhibited by the teeth are suggestive of *Ticholeptus* or of some closely allied type.

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[1] J. W. Gidley, Bull. Amer. Mus. Nat. Hist., vol. 19, pp. 477-482, 1903.

In the collection are several lower premolars which possess characters considered by Loomis[1] as indicative or perhaps diagnostic of the genus *Ticholeptus.* Two specimens of P$\overline{4}$ show a well-developed bifurcation of the anterior end of the anterior crescent. Apparently this character is also seen in *Metoreodon,* but in the latter genus the posterior basin of the tooth is reduced and in P$\overline{3}$ the anterior crescent entirely encloses the anterior basin, which is not the case in the Skull Spring material. P$\overline{3}$, No. 387 (fig. 15*a*), in the Skull Spring collection is simple and resembles the illustration of the comparable tooth in *Ticholeptus* as shown by Loomis,[2] except that the posterior basin is open postero-internally. Fourth premolars Nos. 388 and 389 show a postero-external impression or furrow on the outer enamel wall which becomes less conspicuous with further wear. Loomis[3] notes the presence of an external infolding of the enamel on the premolars in *Metoreodon.*

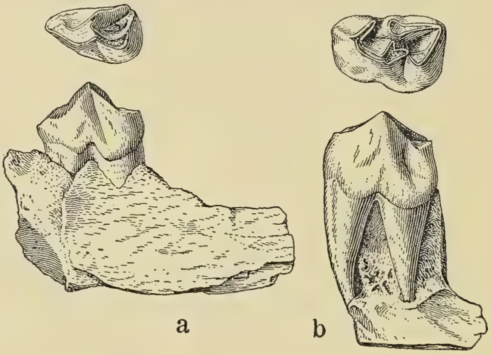

FIG. 15, *a* and *b*—*Ticholeptus* ? sp. *a*, P$\overline{3}$, No. 387 C.I.T. Coll., lateral and occlusal views; *b*, P$\overline{4}$, No. 388 C.I.T. Coll., lateral and occlusal views; x 1.0. Skull Spring Miocene, Oregon.

A specimen representing apparently a large oreodont premolar in the collection may demonstrate the presence of another form generically distinct from *Ticholeptus*(?) sp., with size characteristics like those of *Merycochoerus.*

Dromomeryx, near borealis (Cope)

Four horn-core fragments, two of which are fairly well preserved, and several isolated jaw fragments and teeth in the collection indicate the presence of *Dromomeryx* in the fauna.

The best specimen, a left horn-core, No. 351, retains a part of the supra-orbital margin and about six inches of the horn. This specimen resembles the left horn-core seen in the illustration of No. 827 of the Carnegie Museum[4] referred to *Dromomeryx borealis* (Cope), except that the Oregon specimen appears to be more robust. Furthermore, the horn-cores from Skull Spring are markedly curved with the concavity to the front, more so than is indicated in the illustrations of the type of *D. borealis.*

An upper jaw fragment, No. 449 (fig. 17*a*), with portions of M$\underline{2}$ and M$\underline{3}$ referred to this genus, shows a small accessory lobe on the posterior side of M$\underline{3}$. This is not seen in the figures given by Douglass[5] for either *D. borealis* or *D. americanus*(?).

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[1] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, pp. 1-17, 1924.

[2] F. B. Loomis, *ibid.*, p. 11, 1924.

[3] F. B. Loomis, Amer. Jour. Sci., ser. 4, vol. 50, p. 289, 1920.

[4] Earl Douglass, Ann. Carnegie Mus., vol. 5, pl. 59, 1909.

[5] Earl Douglass, *ibid.*, pl. 63, 1909.

The character of most of the lower teeth of this form is known from three lower jaw fragments, Nos. 349, 350 and 450, which indicate a rather large species. No. 350 (fig. 17*b*) has P$\overline{3}$, P$\overline{4}$ and M$\overline{1}$ complete. The teeth are relatively longer anteroposteriorly and narrower than in *Dromomeryx whitfordi* Sinclair[1] from the Snake Creek beds. The jaws and teeth are noticeably larger than in *D. americanus* and possibly *D. madisonius*. Compared with *D. borealis* the Skull Spring form may not be larger, and a close resemblance is seen in the pattern of the lower teeth, although the "Palæomeryx-fold" is not so conspicuous in the latter species.

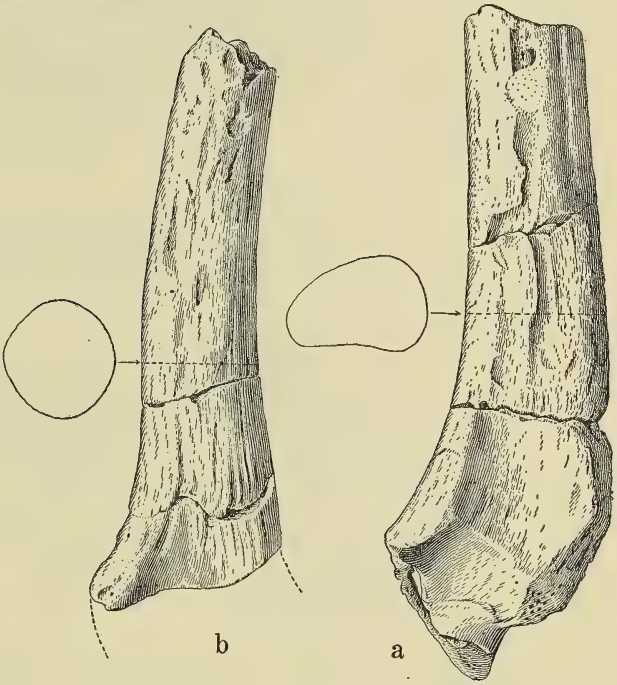

FIG. 16, *a* and *b*—***Dromomeryx,*** near ***borealis*** (Cope). *a*, Left horn-core, No. 351 C.I.T. Coll., outer view; *b*, right horn-core, No. 453 C.I.T. Coll., outer view; x 0.50. Skull Spring Miocene, Oregon.

Measurements

	No. 351	No. 449	No. 350
	mm.	*mm.*	*mm.*
Anteroposterior diameter of horn at point 75 mm. above orbit	36.5	....	....
Transverse diameter of horn at point 75 mm. above orbit	25.0	....	....
M$\underline{3}$, anteroposterior diameter	....	*a* 20.0	....
M$\underline{3}$, greatest transverse diameter	....	*a* 24.0	....
P$\overline{3}$, anteroposterior diameter	....	....	16.0
P$\overline{3}$, greatest transverse diameter	....	....	8.7
P$\overline{4}$, anteroposterior diameter	....	....	16.7
P$\overline{4}$, greatest transverse diameter	....	....	10.5
M$\overline{1}$, anteroposterior diameter	....	....	19.5
M$\overline{1}$, greatest transverse diameter	....	....	12.3

a, approximate.

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[1] W. J. Sinclair, Proc. Amer. Philos. Soc., vol. 54, pp. 94-95, 1915.

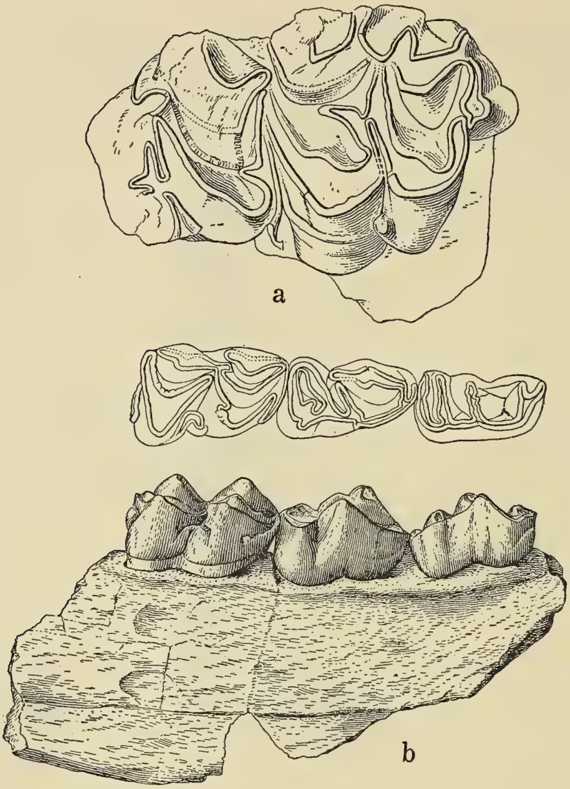


Fig. 17, *a* and *b*—*Dromomeryx,* near *borealis* (Cope). *a,* Fragmentary left upper molars, $M\underline{2}$ and $M\underline{3}$, No. 449 C.I.T. Coll., occlusal view, x 1.5; *b,* fragment of right ramus of mandible with $P\overline{3}$, $P\overline{4}$ and $M\overline{1}$, No. 350 C.I.T. Coll., lateral and occlusal views, x 1.0. Skull Spring Miocene, Oregon.

Blastomeryx ? sp.

A milk fourth premolar, No. 452 (fig. 18*a*), and an upper molar, No. 451 (fig. 18*b*), in the collection may represent the occurrence of *Blastomeryx* in the Skull Spring fauna, although these teeth are of relatively large size. The milk tooth is decidedly brachydont and carries an external basal

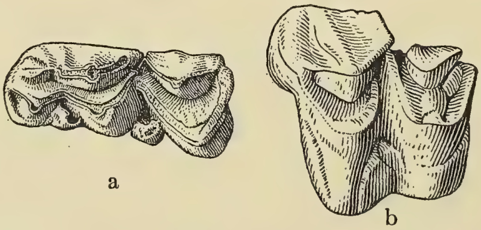


Fig. 18, *a* and *b*—*Blastomeryx* ? sp. *a,* $Dp\overline{4}$, No. 452 C.I.T. Coll., occlusal view; *b,* upper molar, No. 451 C.I.T. Coll., occlusal view; x 2.0. Skull Spring Miocene, Oregon.

cuspule between the first and second columns as well as one between the second and third. The enamel basin of the third column is separate, but those of the first and second columns are confluent. The referred upper molar is also very brachydont and has an internal cingulum and cuspule between the protocone and hypocone.

Measurements

Anteroposterior diameter of upper molar	*a*13. *mm.*
Transverse diameter of upper molar	*a*12.8
Anteroposterior diameter of milk P$\overline{4}$	15.
Greatest transverse diameter of milk P$\overline{4}$	6.8

a, approximate.

Merycodus ? sp. a

An immature lower jaw, No. 383, with Dp$\overline{4}$ and the first two molars in place, appears referable to this genus or possibly to *Blastomeryx*. An upper molar, No. 384, may belong to the same species.

Dp$\overline{4}$, No. 383 (fig. 19*a*), is well worn, so that the enamel lakes in the first two columns are much reduced. A basal cuspule is present on the outer side between the second and third columns, but not between the first and second. This tooth is smaller than the milk tooth which is referred to *Blastomeryx* ? sp. The two molar teeth are rather hypsodont, the second molar showing very little wear. A basal cuspule occurs between the protoconid and hypoconid columns in M$\overline{1}$; however, M$\overline{2}$ does not show this character. M$\overline{3}$ has apparently not erupted. The anterior fold or projection of the cingulum which characterizes the lower molars of *Blastomeryx* is very much reduced, being represented by only a feeble ridge which does not extend to the occlusal surface. The anterior column of both molars exhibits a noticeable postero-external flexure which becomes indistinct with further wear.

This specimen possesses apparently an association of characters similar to that recorded for *Merycodus* ? *ramosus* (Cope) by Matthew.[1] The molars approach in degree of hypsodonty those seen in *Merycodus*, and the anterior cingular projection of the lower molars is reduced as in this genus. However, size, the presence of an external basal cuspule in M$\overline{1}$, and the brachydont Dp$\overline{4}$ are characters suggestive of *Blastomeryx*.

Measurements

Dp$\overline{4}$-M$\overline{2}$ inclusive	29.3 *mm.*
Depth of jaw below M$\overline{2}$ along inner side	*a*17.
Dp$\overline{4}$, anteroposterior diameter	10.4
Dp$\overline{4}$, greatest transverse diameter	4.1
M$\overline{1}$, anteroposterior diameter	9.1
M$\overline{1}$, greatest transverse diameter	4.5
M$\overline{2}$, anteroposterior diameter	10.2
M$\overline{2}$, greatest transverse diameter	4.5

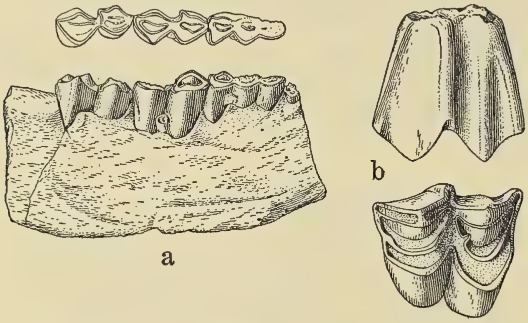
a, approximate.

---

[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 20, pp. 122-123, 1904.

Merycodus ? sp. b

The single first column of a very hypsodont M$\overline{3}$(?), No. 385 (fig. 20), may represent a more advanced species of *Merycodus* in the fauna. The form is apparently as large and as progressive as ?*Merycodus altidens* Matthew[1] from the Upper Snake Creek beds.



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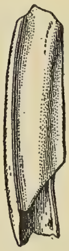

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FIGS. 19, *a* and *b*—*Merycodus* ? sp. a. *a*, Right ramus of mandible with Dp$\overline{4}$, M$\overline{1}$ and M$\overline{2}$, No. 383 C.I.T. Coll., lateral and occlusal views, x 1.0; *b*, upper molar, No. 384 C.I.T. Coll., lateral and occlusal views, x 2.0. Skull Spring Miocene, Oregon.

FIG. 20—*Merycodus* ? sp. b. Fragment of molar, No. 385 C.I.T. Coll., lateral view; x 1.0. Skull Spring Miocene, Oregon.

Measurements

Height of column	*a*30. *mm.*
Greatest anteroposterior length	7.8
Greatest transverse width	6.3

---

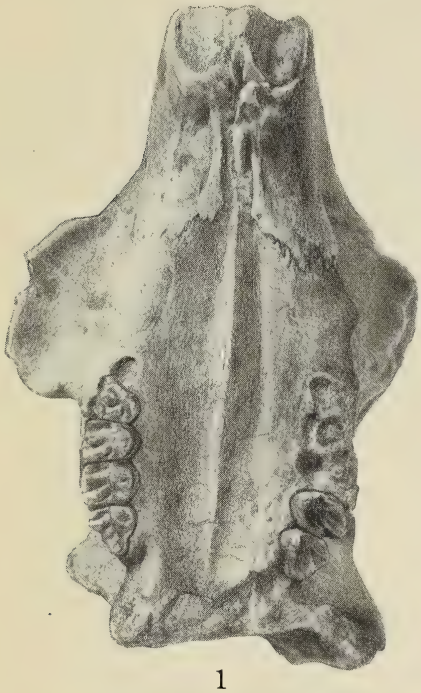
a, approximate.

[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 200-201, 1924.

PLATE 1

FIGS. 1, 1*a*—*Sciurus malheurensis* n. sp. Skull, No. 129 C.I.T. Coll. Fig. 1, ventral view; Fig. 1*a*, lateral view; x 2.5.

FIGS. 2, 2*a*, 2*b*—*Sciurus tephrus* n. sp. Skull, No. 332 C.I.T. Coll. Fig. 2, ventral view; fig. 2*a*, lateral view; fig. 2*b*, dorsal view; x 2.5. Skull Spring Miocene, Oregon.



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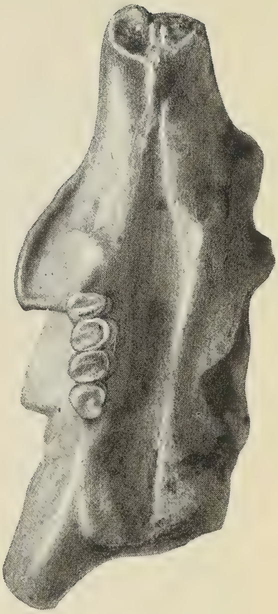

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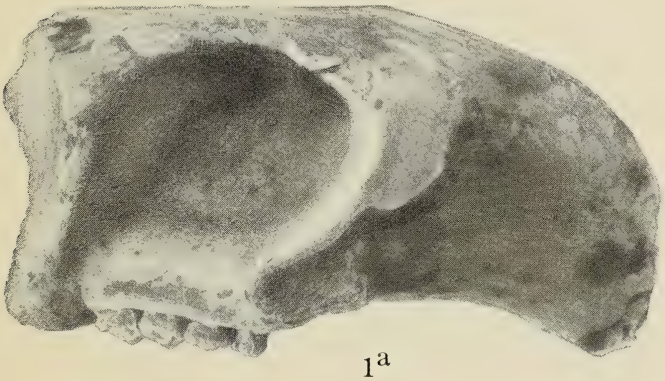

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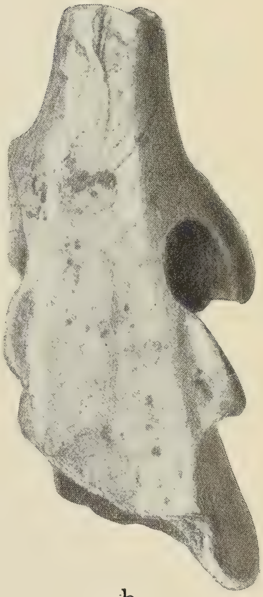
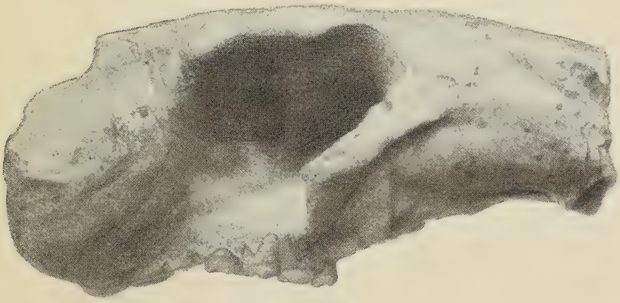


2^b



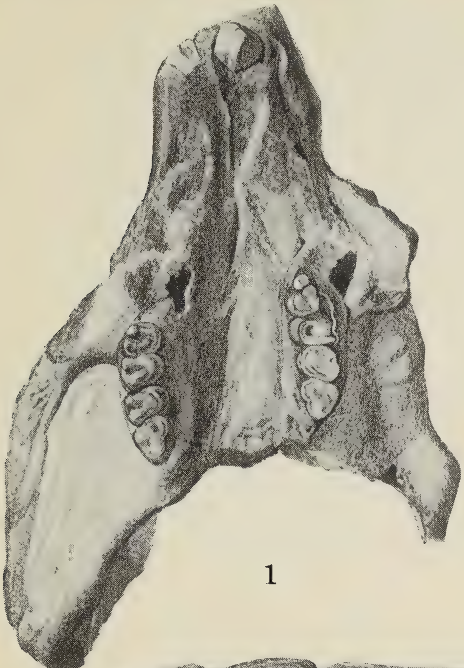
2^a

PLATE 2

FIGS. 1, 1*a*—*Citellus ridgwayi* n. sp. Skull, No. 334 C.I.T. Coll. Fig. 1, ventral view; fig. 1*a*, lateral view; x 2.5.

FIGS. 2, 2*a*—Skull, No. 335 C.I.T. Coll. Fig. 2, ventral view; fig. 2*a*, lateral view; 2.5.

FIG. 3—*Sciurus malheurensis* n. sp. Skull, No. 333 C.I.T. Coll. Lateral view; x 2.0. Skull Spring Miocene, Oregon.



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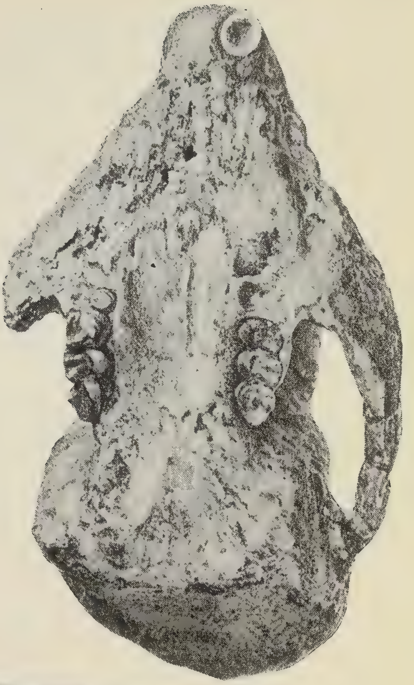

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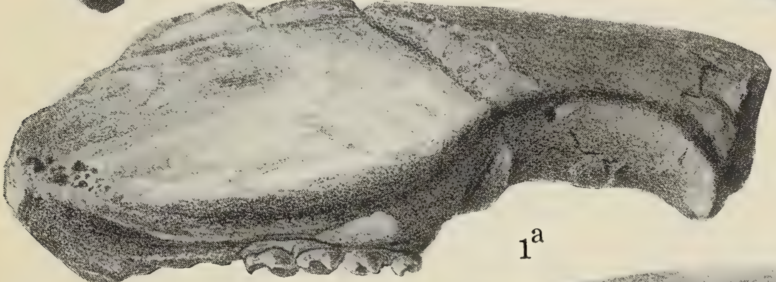

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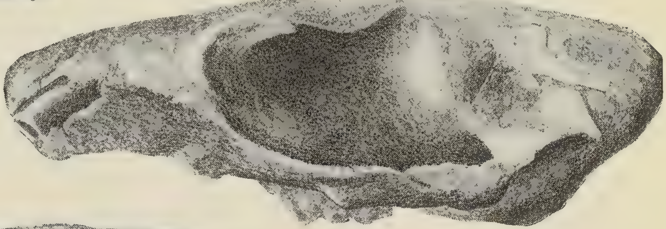

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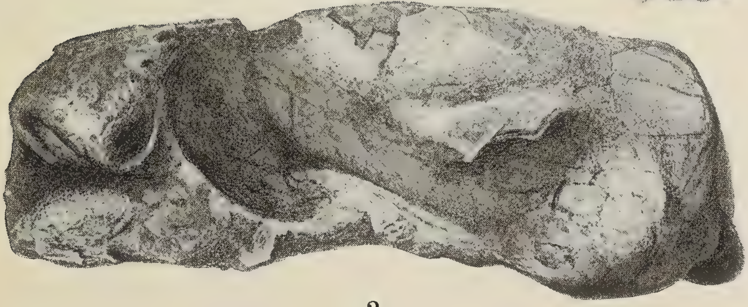


3

Plate 3

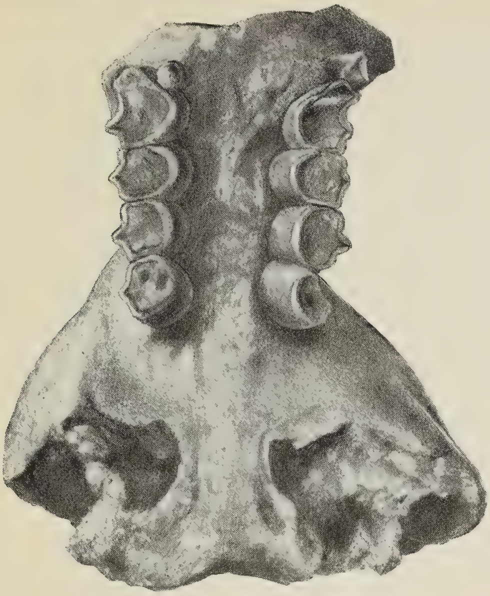
Liodontia alexandræ (Furlong). Skull Spring Miocene, Oregon.

Figs. 1, 1*a*, 1*b*—Skull, No. 321 C.I.T. Coll. Fig. 1, ventral view; fig. 1*a*, lateral view; fig. 1*b*, dorsal view; x 3.0.

Fig. 2—Superior dentition, No. 322 C.I.T. Coll., occlusal view, x 3.0.

Fig. 3—Superior dentition, No. 323 C.I.T. Coll., occlusal view, x 3.0.

Figs. 4, 4*a*—Immature superior dentition, No. 326 C.I.T. Coll. Fig. 4, occlusal view; fig. 4*a*, lateral view; x 5.0.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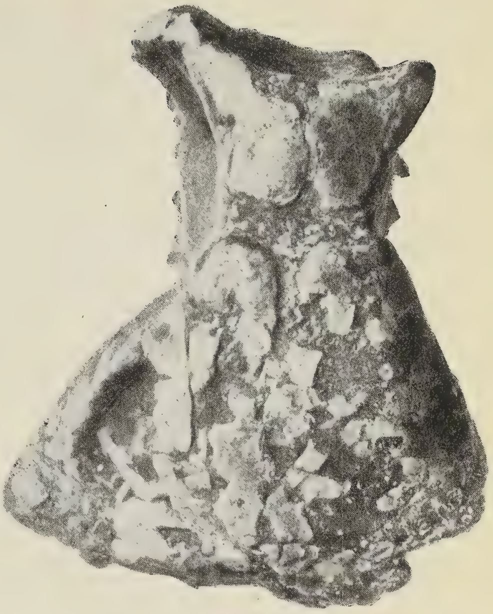
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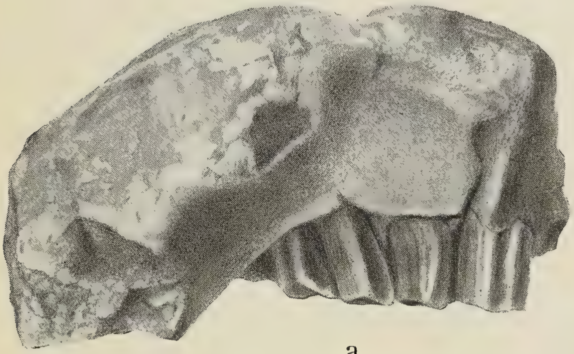
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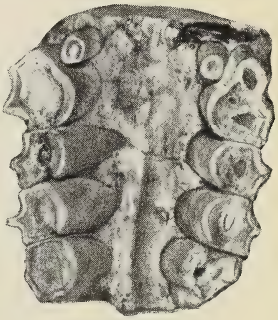
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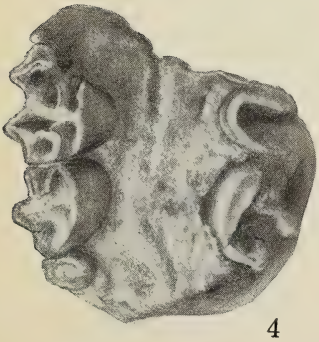
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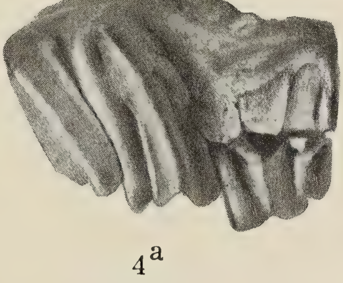
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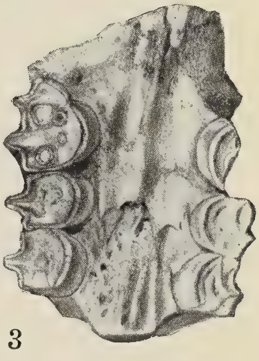
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Plate 4

Liodontia alexandræ (Furlong)

Fig. 1—Right ramus of mandible, No. 331 C.I.T. Coll. Occlusal view of dentition, x 3.0.

Fig. 2—Right ramus of mandible, No. 329 C.I.T. Coll. Occlusal view of dentition, x 3.0.

Figs. 3, *3a*, *3b*—Left ramus of mandible, No. 330 C.I.T. Coll. Fig. 3, occlusal view of dentition; figs. *3a*, *3b*, lateral views; x 3.0.

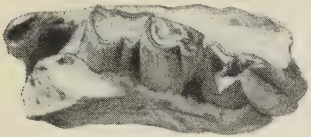
Figs. 4, *4a*, *4b*—Left ramus of mandible, No. 328 C.I.T. Coll. Fig. 4, occlusal view of dentition; figs. *4a*, *4b*, lateral views; x 3.0.

Figs. 5, *5a*, *5b*—Left ramus of mandible, No. 327 C.I.T. Coll. Fig. 5, occlusal view of dentition; figs. *5a*, *5b*, lateral views; x 3.0.

Mylagaulus, cf. *lævis* Matthew

Fig. 6—Immature superior dentition, No. 366 C.I.T. Coll. Occlusal view, x 2.0.

Skull Spring Miocene, Oregon.



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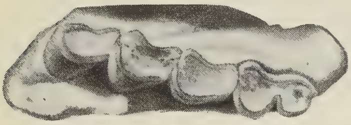

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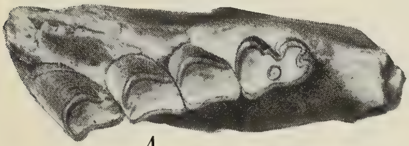

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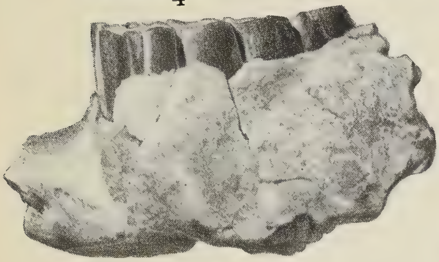

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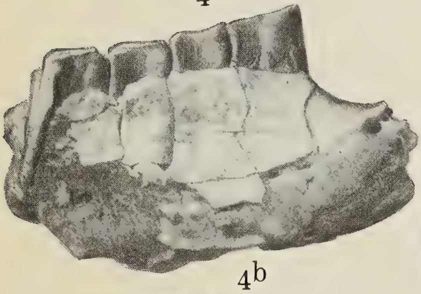

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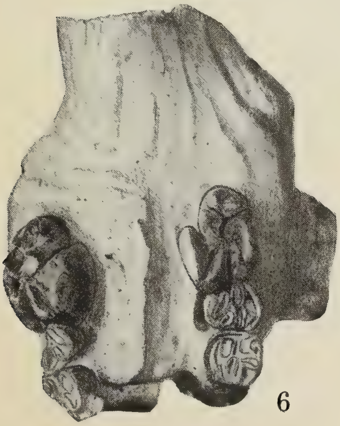

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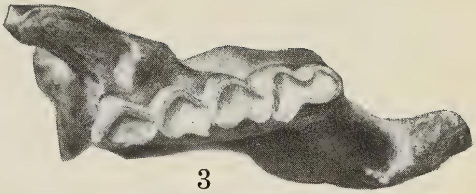

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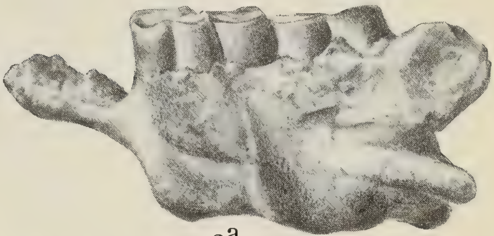

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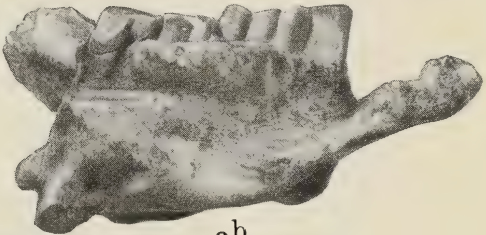

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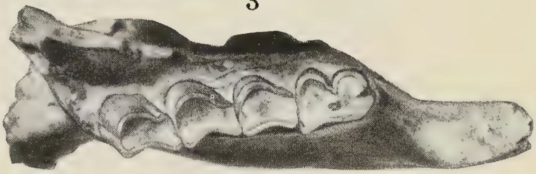

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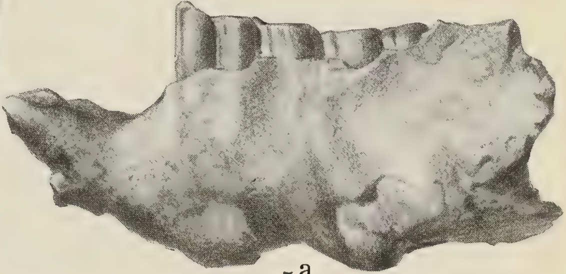

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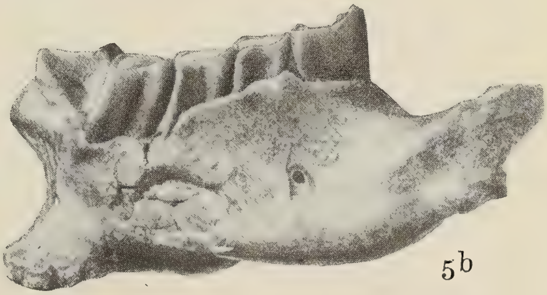


5b

PLATE 5

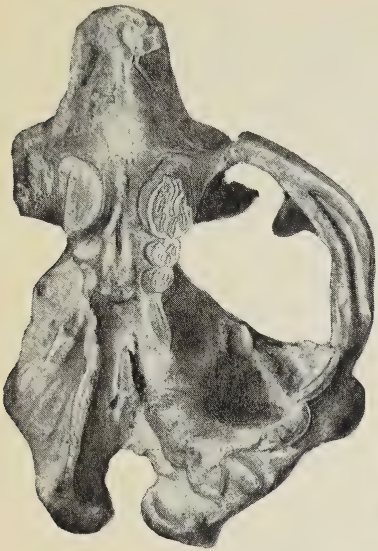
Mylagaulus, cf. *lævis* Matthew. Skull Spring Miocene, Oregon.

FIGS. 1, 1*a*, 1*b*—Skull, No. 68 C.I.T. Coll. Fig. 1, ventral view; fig. 1*a*, dorsal view; fig. 1*b*, lateral view; x 1.0.

FIGS. 2, 2*a*, 2*b*—Left ramus of mandible, No. 70 C.I.T. Coll. Fig. 2, dorsal view, x 2.0; figs. 2*a*, 2*b*, lateral views, x 1.0.

FIGS. 3, 3*a*, 3*b*—Left ramus of mandible, No. 369 C.I.T. Coll. Fig. 3, dorsal view, x 2.0; figs. 3*a*, 3*b*, lateral views, x 1.0.

FIGS. 4, 4*a*, 4*b*—Left ramus of mandible, No. 368 C.I.T. Coll. Fig. 4, dorsal view, x 2.0; figs. 4*a*, 4*b*, lateral views, x 1.0.



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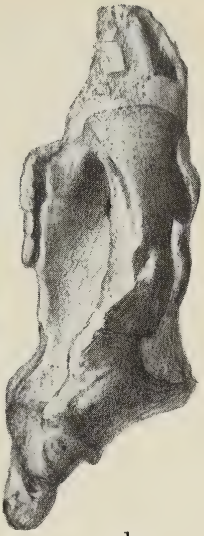

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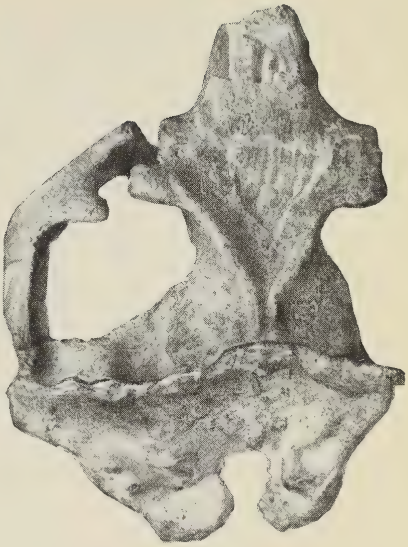

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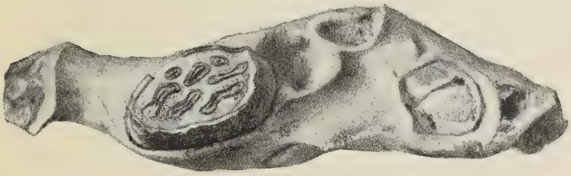

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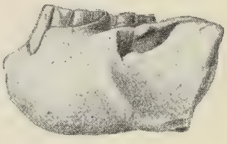

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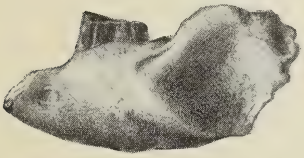

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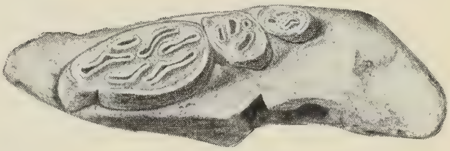

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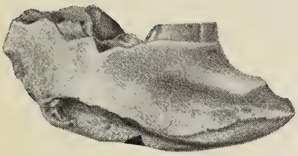

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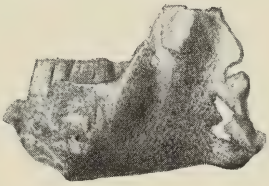

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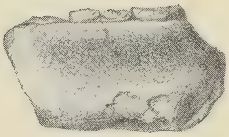

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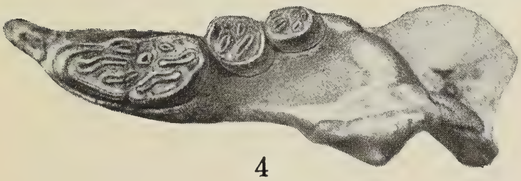

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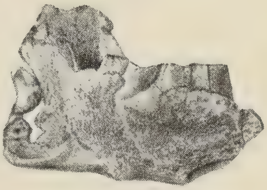


4^b

Plate 6

Diprionomys ? oregonensis n. sp.

Figs. 1, 1*a*—Skull, No. 370 C.I.T. Coll. Fig. 1, ventral view; fig. 1*a*, lateral view; x 4.0.

Figs. 2, 2*a*—Skull, No. 371 C.I.T. Coll. Fig. 2, occlusal view of superior dentition, x 4.0; fig. 2*a*, dorsal view, x 2.0.

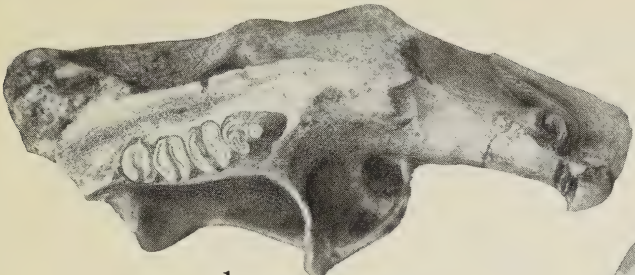
Figs. 3, 3*a*—Skull, No. 372 C.I.T. Coll. Fig. 3, occlusal view of superior dentition, x 4.0; fig. 3*a*, dorsal view, x 2.0.

Fig. 4—Inferior dentition, No. 371 C.I.T. Coll. Occlusal view, x 4.0.

Mylagaulus, cf. *lævis* Matthew

Fig. 5—Fourth premolars, Nos. 516-531 incl. C.I.T. Coll. 1st and 2d rows, right and left P$\overline{4}$; 3d and 4th rows, right and left P$\underline{4}$; occlusal views; x 2.0.

Skull Spring Miocene, Oregon.



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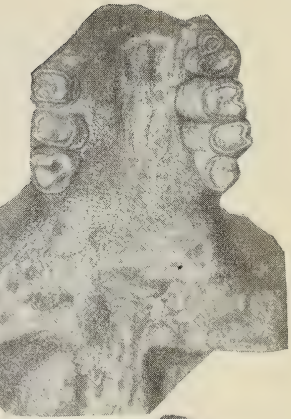

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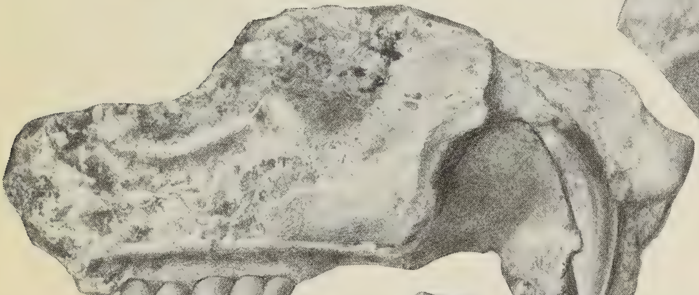

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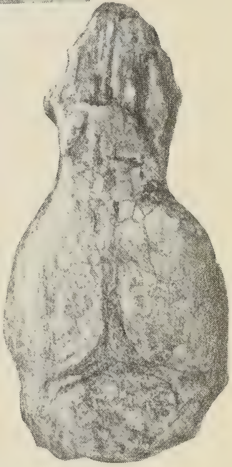

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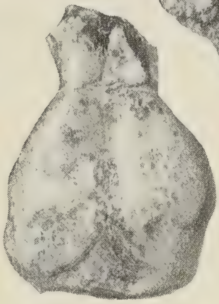

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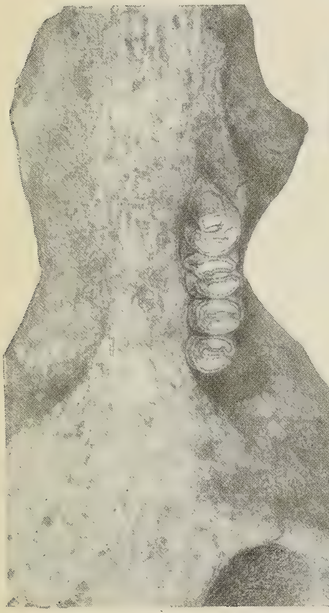

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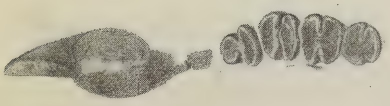

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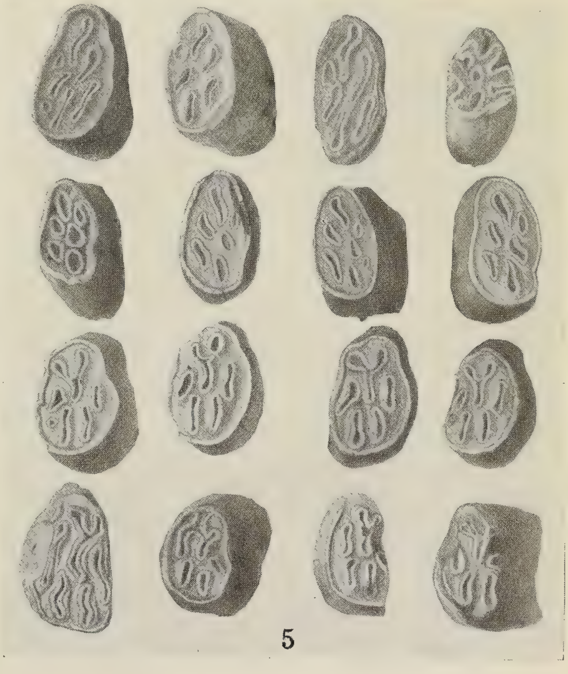

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IV

ADDITIONS TO THE MAMMALIAN FAUNA FROM THE TECUYA BEDS, CALIFORNIA

By Chester Stock

With one plate

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ADDITIONS TO THE MAMMALIAN FAUNA FROM THE TECUYA BEDS, CALIFORNIA

INTRODUCTION

In 1920 Stock[1] described the fragmentary remains of three mammalian types (*Hypertragulus* sp., *Cœnopus* or *Diceratherium,* and a sciurid) from the Tecuya beds of Tecuya Canyon, California. Although the region was visited on several occasions during the past ten years, no additions were made to the vertebrate fauna until the summer of 1930, when a field party from the California Institute of Technology obtained materials of an oreodont and of a canid type.

The Tecuya beds may be the correlative of at least a portion of the Sespe deposits of southern California, which they resemble in certain stratigraphic relationships and lithologic characteristics. Since the description of the very incomplete fauna from this locality, mammalian remains have been collected in the upper Sespe of South Mountain, Ventura County. In view of the importance of establishing more clearly the faunal relations of these horizons, any additions to the assemblages are especially welcome. Record is therefore made of the newly obtained specimens from the Tecuya.

Promerycochœrus erythroceps n. sp.

Type specimen—No. 486 Calif. Inst. Tech. Coll., the anterior end of a skull with third incisor, premolars 1 to 4, and an incomplete first molar present.

Locality—Tecuya beds, Lower Miocene or Upper Oligocene, Tecuya Canyon, Kern County, California. C. I. T. Vert. Pale. Coll. Loc. 116.

Specific characters—Size approaching that of *Promerycochœrus superbus.* P$\underline{3}$ without median crest and with anterior and posterior basins confluent.

Description—The red or maroon clay in which the specimen was found has imparted a red color to the skull and teeth. This has suggested the specific name. Although lacking entirely that portion of the skull behind the fourth premolar and the anterior ends of the nasals, No. 486 fortunately retains the upper premolar teeth.

The fragment of M$\underline{1}$ shows considerable wear, but the premolars are moderately worn. In P$\underline{4}$ a well-defined cingulum is present along the entire inner side. There is evidently no pit present at the antero-external corner of this tooth.

In P$\underline{3}$ the anterior intermediate crest (of Loomis) is strongly developed and assists in the formation of an anterior enamel lake, but there is no evidence of a median crest. While the tip of the principal cusp is somewhat worn and the tooth is otherwise not entirely perfect in its preservation, the absence of the median crest can be definitely established. The inner anterior wall (anterior crescent) sweeps backward beyond the area of contact with the anterior intermediate crest and meets the forward extension of the thickened posterior crescent. This contact is clearly defined not only on the free edge but also along the entire height of the inner wall of the tooth.

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[1] C. Stock, Univ. Calif. Publ. Bull. Dept. Geol., vol. 12, pp. 267-276, 6 figs. in text.

The third premolar is particularly noteworthy because of total absence of a median crest. Loomis [1] has indicated that in *Promerycochœrus* this crest is weakly developed and there is consequently a suggestion of union of the anterior and posterior basins. In the Tecuya form this union has evidently been consummated, in which respect No. 486 differs from specimens of *Promerycochœrus* from the John Day and Lower Rosebud. In *Mesoreodon,* according to Loomis, the rear basin of $P\underline{3}$ is enclosed by the posterior crescent.

$P\underline{2}$ resembles the comparable tooth in specimens of *Promerycochœrus* from the John Day. A maxillary eminence, situated immediately above the postero-external rim of the alveolus for the canine, is sharply defined. Posterior to the end of the maxillonasal notch the nasals are broad, while anterior to this end they taper forward to their tips in a distance of 32 mm. In the appearance of the muzzle and the character of the nasal elements, No. 486 resembles *Promerycochœrus* much more closely than it does *Merycochœrus.*

Unfortunately there are at present no corresponding parts of skulls on which a direct comparison can be made between *P. erythroceps* and *Promerycochœrus*(?) *hesperus* from the upper Sespe of South Mountain. These types occur in deposits which may be of nearly the same age. The two forms apparently resemble each other in size.

Measurements (in millimeters) of No. 486

Length of premolar series, anterior end of $P\underline{1}$ to posterior end of $P\underline{4}$	59.3
$P\underline{1}$, anteroposterior diameter	15.4
$P\underline{1}$, transverse diameter	*a*7.8
$P\underline{2}$, anteroposterior diameter	16.7
$P\underline{2}$, greatest transverse diameter	10.1
$P\underline{3}$, anteroposterior diameter	16.2
$P\underline{3}$, greatest transverse diameter	11.7
$P\underline{4}$, anteroposterior diameter	14.5
$P\underline{4}$, greatest transverse diameter	17.
$I\underline{3}$, transverse diameter	8.5
Width of palate between alveoli for first premolars	*a*58.5
Width of muzzle across maxillary eminences situated above canines	*a*77
Width across nasals at maxillo-nasal notch	38.6
Greatest anteroposterior diameter of anterior palatine foramen	22.8
Greatest transverse diameter of anterior palatine foramen	13.3

a, Approximate.

Daphœnus(?) ruber n. sp.

Type specimen—No. 845 Calif. Inst. Tech. Coll., a fragment of the left ramus of the mandible with $P\overline{4}$, $M\overline{1}$ and $M\overline{2}$ and with the alveoli for $P\overline{2}$, $P\overline{3}$ and $M\overline{3}$.

Locality—Tecuya beds, Tecuya Canyon, Kern County, California. Calif. Inst. Tech. Vert. Pale. Loc. 116.

Specific characters—Size slightly smaller than that of *Daphœnus vetus.* Trigonid area of $M\overline{2}$ contracted in anteroposterior direction with paraconid more reduced than in *D. vetus.* Size of teeth more nearly like that of *Paradaphœnus transversus* than like that of *Pericyon socialis,* but with jaw larger, relative to size of teeth, than in former species. Basins of molars shallow as in *Daphœnus,* differing noticeably in this respect from *Paradaphœnus,* less so from *Pericyon.*

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[1] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, p. 10, 1924.

Description—In No. 845 the lower premolars were long and, judged in the light of the character of $P\overline{4}$, possessed crowns which were compressed laterally. The crushing portion of the dentition is well developed with the molars of different type than those of *Temnocyon* and *Mesocyon.*

The crown of $P\overline{4}$ exhibits in addition to the principal cusp and posterior tubercle a small and narrow anterior shelf and a more extensive posterior shelf slightly ridged along the median line. No. 12450 Amer. Mus. Coll., a well-preserved skull from the Oreodon beds of the Brule formation, South Dakota, possesses a fourth lower premolar almost identical with that of the Tecuya species in size and in structure of crown.

$M\overline{1}$ shows also considerable resemblance to the comparable tooth in *Daphœnus.* The metaconid is large, the hypoconid also large but low, and the basin of the heel shallow and bordered along the inner posterior side by a very low ridge. No entoconid is present as in *Cynodesmus.*

The trigonid region of $M\overline{2}$ is well worn. Well-developed protoconid and metaconid were present, but the paraconid was evidently reduced or absent. This is suggested by the wearing surface and by the greater contraction of the trigonid area in anteroposterior direction than in *Daphœnus.* Judging from the size of the alveolus, $M\overline{3}$ was relatively as large as that in the latter genus. No. 845 differs principally from No. 12450 in structure of crown of $M\overline{2}$ and in the shape of the ramus.

In the Tecuya specimen the heels of the molars are not so wide nor so deeply excavated to form pronounced basin-shaped depressions as in *Paradaphœnus cuspigerus* and in these characters greater resemblance is shown to *Daphœnus.* In $M\overline{2}$ the length of the trigonid in relation to the length of the tooth is shorter than in *Daphœnus* (No. 12450 Amer. Mus.) and in this respect greater approach is made to the type of *P. cuspigerus.* It is possible that in the latter this length is less than in the Tecuya specimen, but the difference is not great.

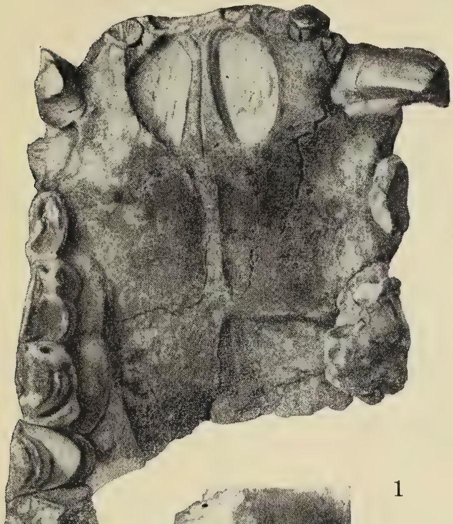
A larger mandible of *Paradaphœnus* from the John Day, No. 12714 Yale Peabody Mus. Coll., has been referred to *P. transversus.* No. 12714 resembles the Tecuya specimen more nearly in size of teeth but the ramus is more slender. The molars exhibit deep basins and $M\overline{3}$ appears to have been smaller than in the Californian form.

Pericyon socialis is a distinctly larger type than No. 845. $P\overline{4}$ may be relatively heavier than in the latter, but the molar teeth show resemblance to those in the Tecuya specimen. The basins are shallower than in *Paradaphœnus* but not so shallow as in No. 845. $M\overline{3}$ is relatively large. In the essential characters of the heel of $M\overline{1}$, shallowness of basins in $M\overline{2}$, reduction of paraconid in the second molar, as well as the inferred large size of $M\overline{3}$, the Tecuya form is more like *Pericyon* than like *Paradaphœnus.* No. 845 differs from *Pericyon* in size and to a less extent in the character of $P\overline{4}$.

It is evident that *Daphœnus, Paradaphœnus, Pericyon* and the Tecuya form represent a group of related canid forms, with the last three somewhat advanced beyond the stage of development represented by *Daphœnus* from the White River. Possibly the type from the Tecuya beds will furnish, when better known, a connecting link between *Daphœnus* and *Pericyon.*

Comparative Measurements (in millimeters)

	Daphœnus (?) ruber n. sp. Type, No. 845 C.I.T. Coll.	Daphœnus vetus No. 10066 Y.P.M.	Daphœnus sp. No. 12450 A.M.N.H.	Daphœnus hartshornianus No. 1387 A.M.N.H.	Pericyon socialis Type No. 12715 Y.P.M.	Paradaphænus cuspigerus Type No. 6852 A.M.N.H.	Paradaphænus transversus No. 12714 Y.P.M.
Length from anterior end of P$\overline{4}$ to posterior end of M$\overline{2}$.......	33.0	34.7	32.7	31.6	40.4	22.1	34.0
P$\overline{4}$, anteroposterior diameter....	11.5	11.4	11.0	....	13.1	7.7	11.8
P$\overline{4}$, greatest transverse diameter.	4.4	5.3	4.3	....	6.0	3.3	4.6
M$\overline{1}$, anteroposterior diameter...	13.7	14.9	13.6	13.7	17.1	9.2	14.5
M$\overline{1}$, greatest transverse diameter of heel................	6.0	7.2	6.8	6.3	8.0	5.1	6.2
M$\overline{2}$, anteroposterior diameter...	8.1	9.0	8.3	8.3	11.0	5.9	8.0
M$\overline{2}$, greatest transverse diameter across protoconid-metaconid......................	5.7	6.2	5.6	5.7	6.6	4.1	5.2
M$\overline{2}$, greatest transverse diameter across heel............	4.8	5.7	5.4	5.0	6.2	4.4	5.2



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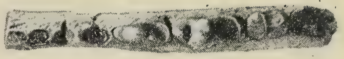

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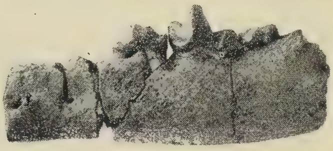

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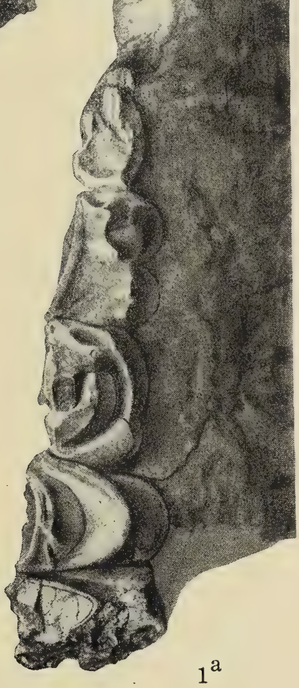

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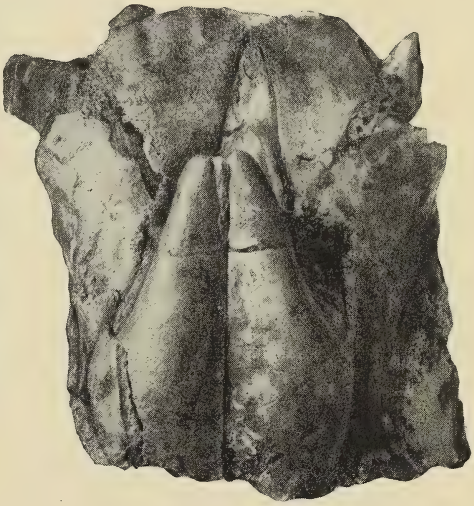

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FIGS. 1, 1*a*, 1*b*—***Promerycochœrus erythroceps*** n. sp. Type specimen, anterior portion of skull, No. 486 C.I.T. Fig. 1, palatal view; fig. 1*b*, dorsal view; x 2/3. Fig. 1*a*, occlusal view of cheek-teeth, slightly larger than natural size. Tecuya beds, Tecuya Canyon, Calif.

FIGS. 2, 2*a*—***Daphœnus*** (?) *ruber* n. sp. Type specimen, ramus, No. 845 C.I.T., lateral and occlusal views; x 2/3. Tecuya beds, Tecuya Canyon, Calif.

V

A NEW GENUS OF OTTER FROM THE PLIOCENE OF THE NORTHERN GREAT BASIN PROVINCE

By Eustace L. Furlong

With two plates

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A NEW GENUS OF OTTER FROM THE PLIOCENE OF THE NORTHERN GREAT BASIN PROVINCE

INTRODUCTION

Systematic collecting over a number of years in the Thousand Creek beds of northwestern Nevada has furnished one of the largest and best-known mammalian faunas from the Pliocene of the Great Basin province. Among the carnivores recorded in the assemblage are several mustelid forms. To this list is now added a representative of the Lutrinæ, based on material secured by the California Institute of Technology in the Thousand Creek beds during the field season of 1929.

The discovery of this material has led to the recognition of a related type in the Rattlesnake Pliocene fauna of the John Day region, Oregon. Thus, added information becomes available concerning the relationships of the Thousand Creek and Rattlesnake faunas.

Mustelid types are not uncommon in later Tertiary faunas of western America, but it is noteworthy that forms having a direct ancestral relationship to the modern otters are wholly lacking in the record or are but doubtfully established. The present material from the middle and earlier Pliocene aids in extending backward the history of the lutrine division of the Mustelidæ, at least to this stage in the Tertiary.

ACKNOWLEDGMENTS

The writer is indebted to Dr. Chester Stock for interest in the present study and for his criticism of the manuscript. Recent otter skulls were made available by Mr. Donald R. Dickey of the California Institute of Technology. Loan of fossil material from the Rattlesnake Pliocene was kindly granted by Dr. Charles L. Camp of the Paleontological Museum, University of California. Mr. John L. Ridgway made the drawings, retouched the photographs and assembled the plates.

LUTRINÆ

Lutravus halli n. gen. and n. sp.

Type—No. 478 C. I. T. Vert. Pale. Coll., an anterior portion of a skull with superior teeth represented, except the incisors and first premolars. The type is named for Dr. E. Raymond Hall in recognition of his important studies of Recent and fossil Mustelidæ.

Referred specimen—No. 643, C. I. T. Vert. Pale. Coll., a posterior fragment of the right ramus with $P\overline{4}$, $M\overline{1}$ and the alveolus for $M\overline{2}$.

Locality—Thousand Creek beds yielding remains of *Hipparion, Sphenophalos* and *Hypolagus,* approximately one mile west of the Hot Spring in

Thousand Creek flats; C. I. T. Coll. Loc. 63. The type occurred in a light buff-colored, fine sand. The paratype was found nearby in the same horizon, but represents a second individual.

Generic diagnosis—Dental formula $\frac{3}{3?}$, $\frac{1}{1?}$, $\frac{4}{3}$, $\frac{1}{2}$. Superior dentition: Teeth more robust and canine less curved than in *Lutra*. Diastema between third incisor and canine short. $P\underline{1}$ farther removed behind canine than in *Lutra*. $P\underline{2}$ and $P\underline{3}$ with single cusp, not basined posteriorly. $P\underline{4}$ with protocone narrow anteroposteriorly and situated well posterior to paracone root. $M\underline{1}$ rectangular, not subquadrate, and with only slight posterior expansion of heel. Inferior dentition: $P\overline{4}$ robust, situated close to $M\overline{1}$, and with apex of principal cusp inclined posteriorly. Posterior heel absent and cingulum not well developed. $M\overline{1}$ narrow with trigonid elongate and with short talonid. Metaconid small and postero-internal to protoconid.

Specific diagnosis—Superior and inferior teeth robust. Upper carnassial and Molar $\underline{1}$ more like comparable teeth in European *Lutra lutra* than like those of *Lutra canadensis pacifica*. $P\underline{4}$ with inner basin behind protocone small, root of protocone posterior. $M\underline{1}$ rectangular. $M\overline{1}$ lacks the characteristic widening of the trigonid region seen in modern otters and the metaconid is small.

COMPARISONS

SUPERIOR DENTITION

Lutravus differs from *Lutra lutra* Linnæus, *Lutra canadensis pacifica* Rhoads, the Pleistocene *L. palæindica* and other Lutrinæ in details of its dentition. In some characters the teeth are like those in *Brachypsalis* and in *Martes*. The molars have been reduced to $M\underline{1}$ as in the more specialized *Lutra*, but $P\underline{1}$ was probably not so reduced. The carnassial is more generalized and approaches the *Brachypsalis* type of tooth.

The alveoli for the incisors show that these teeth were deeply rooted and increased in size from $I\underline{1}$ to $I\underline{3}$. The third incisor was apparently a larger, heavier tooth than in *Lutra*, approaching in relative size that in *Gulo*.

The crown of the canine is long and exhibits a curvature less than that in *Lutra*.

The alveolus for $P\underline{1}$ indicates a peg-like, single-rooted tooth. The socket is situated slightly farther behind the canine and more in alignment with the principal axis of the tooth-row than in *Lutra*.

The second premolar is relatively heavy with two roots and a crown with a single cusp. The latter cusp is high, with apex slightly anterior to the margin of the posterior root. The tooth widens posteriorly at the cingulum but is not basined as in *L. canadensis pacifica* (Plate 1, fig. 8) or in *L. lutra* (Plate 1, fig. 2).

$P\underline{3}$ is double-rooted with robust crown. The principal cusp is likewise heavy, more so than in *L. canadensis pacifica* or *L. lutra*. An internal cingulum rises into a definite buttress at the base of the cusp and continues as a ridge which extends toward the apex. This tooth is broader posteriorly than in *Lutra lutra* but its breadth is relatively not so great as in *L. canadensis pacifica*. A posterior basin present in $P\underline{3}$ of *L. lutra* and *L. canadensis pacifica* is absent in *Lutravus*.

$P\underline{4}$ is a strongly developed, trigonal, sectorial tooth. The position of the protoconal root is well posterior to the paraconal root, more so than in *L. lutra* and *L. canadensis pacifica*. The position is more as in *Mephitis occidentalis occidentalis* and is not anterior to the paraconal root as in *Brachypsalis*.

The protocone is represented by a sharp secant blade as in *Lutra,* not by a rounded blunt cusp as in *Mephitis* or in *Brachypsalis.* The post-protoconal ledge does not form a broad, deep basin as in *L. lutra, L. palæindica* or *L. canadensis pacifica.* The border of this ledge extends to the medial base of the paracone and metacone, terminating at a point more anteriorly situated than in *L. canadensis pacifica* or in *Mephitis.* The configuration of the inner border of this tooth conforms more with that seen in *L. lutra,* but in *Lutravus* the postprotoconal ledge is not so broadly basined. Greater resemblance prevails between *Lutravus* and *L. lutra* than between the former type and *L. canadensis pacifica,* although in the European otter the inner ledge is more broadly basined and the emargination is rounded. In *L. canadensis pacifica* and in *L. palæindica* the transverse broadening of the inner basin extends much farther back along the base of the metacone than in the Thousand Creek type.

The anterior border of the base of the paracone in *Lutravus* does not form a shelf or cuspule so distinct as in the modern representatives of *Lutra* or in *L. palæindica.* The apex of the paracone is situated at a point transversely opposite the protocone and not well posterior to this cusp as in *Brachypsalis.* In *L. palæindica* and in *L. lutra* the position is slightly posterior to the protocone. The metacone is relatively low and the buccal surface is deeply beveled in back of the paracone as in *Lutra* and in *Mephitis.*

M$\underline{1}$ resembles the comparable tooth in *Martes martes* in its rectangular form, as well as that of *Brachypsalis* in some characters. It differs distinctly in shape from the sub-quadrate form of tooth found in *Lutra* and in *Mephitis,* and from the semiquadrate type of tooth occurring in *B. pristinus.* In size and in proportions of crown, M$\underline{1}$ approaches more closely *L. lutra* than it does either *L. canadensis pacifica* or *L. palæindica.*

The paracone and metacone form a distinct antero-posterior ridge set well in from the buccal cingulum. The two cusps are not so deeply separated as in *L. canadensis pacifica, L. lutra* or in *Brachypsalis.* The outer surface of the tooth slopes gently downward from the cingulum to the occlusal edge, whereas in *Brachypsalis* it is steep-sided. In *L. lutra* the outer wall is depressed inward or basined.

The protocone appears as a low crescentic edge rising from the shelf-like transversely elongate lingual third of the tooth. This protoconal ridge extends forward and outward to coalesce with the cingulum at the anterior base of the parastyle. In *Brachypsalis* the protocone is cusp-like and tends to be isolated from the paracone and cingulum. The protocone in *L. lutra* is more widely crescentic and is situated close to the lingual margin of the tooth. In *L. canadensis pacifica* it is a high cuspate ridge that forms the antero-inner face of the tooth. In *L. palæindica* M$\underline{1}$ is lobate in form and the protocone is lateral and anterior to and connects with a rather prominent hypocone.

No distinct hypocone is present. The tooth is expanded in its postero-lingual part to form a shelf-like surface, but is not basined as in *L. lutra, L. canadensis pacifica* or in *Brachypsalis.* The inner border is not emarginate nor does it form a relatively high sharp edge as in *Lutra* and *Brachypsalis.* The inner surface is smoothly rounded in one plane and extends anteroposteriorly from a point in front of the protocone to the expanded posterolingual portion of the tooth.

In occlusal aspect M$\underline{1}$ presents a straight, transverse anterior border and an anteriorly concave posterior border, while in *Brachypsalis modicus* and *B. matutinus* the characters of these borders are reversed. M$\underline{1}$ in *B. pristinus* is more quadrate as in *L. canadensis pacifica.* The inner half of M$\underline{1}$ in *Lutravus* with its somewhat expanded hypoconal heel is not unlike the corresponding part of M$\underline{1}$ in *Martes martes.*

Lutravus is smaller than *L. aonychoides* described by Zdansky from the Hipparion beds of China, and is closer in this respect to *L. lutra.* The superior teeth in *L. aonychoides* approximate in size and character those of *L. canadensis pacifica.* P$\underline{4}$ has the anteroposterior expansion of the lingual shelf as in the true otters. M$\underline{1}$ is subquadrate, the protocone more roundly cuspate than in *Lutravus,* and the heel is widely expanded. I$\underline{3}$ is relatively large, the diastema intervening between the tooth and the canine longer than in *Lutravus,* and the canine inclined more anteriorly than in other lutrine species.

The angle formed by an intersection of the axes parallel to the external surfaces of P$\underline{4}$ and M$\underline{1}$ measures 151° in *Lutravus.* This angle is greater than that measured in *L. lutra* (141°) or in *L. palæindica* (136°) and approaches closely that in *Martes martes* (150°).

Comparative Measurements (in millimeters) of Dentition

	Lutravus C.I.T. No. 478	L. lutra C.I.T. No. 625	L. c. pacifica Dickey Col. No. 18136
Length of tooth row, anterior margin of C to posterior margin of M$\underline{1}$......	39.4	32.4	38.7
Transverse diameter measured between outer surfaces of first upper molars....	15.8	11.5	14.2
C, greatest transverse diameter........	5.5	4.8	5.4
C, greatest long diameter.............	7.3	5.2	6.6
P$\underline{2}$, greatest long diameter.............	5.6	5.0	4.6
P$\underline{2}$, greatest transverse diameter.......	3.7	3.2	3.3
P$\underline{3}$, greatest long diameter.............	7.2	6.4	7.4
P$\underline{3}$, greatest transverse diameter.......	4.5	4.2	4.5
P$\underline{4}$, greatest long diameter.............	11.4	9.8	11.8
P$\underline{4}$, greatest transverse diameter.......	7.9	7.0	8.0
M$\underline{1}$, greatest long diameter............	6.4	6.7	8.7
M$\underline{1}$, greatest transverse diameter.......	10.6	9.7	11.0

INFERIOR DENTITION

A fragment of the right ramus, No. 643 C.I.T., also from the Thousand Creek beds, is considered as belonging to *Lutravus halli.* In this specimen the dorso-ventral diameter of the jaw, the convexity of the inferior border and the crowding of the cheek-teeth indicate a shortening of the jaw. Presumably the anterior premolar teeth were somewhat reduced in size, with P$\overline{1}$ absent. P$\overline{4}$ is a single-cusped tooth resembling that in *Lutra lutra.* The cingulum is not so well developed and the tooth is broader posteriorly than in *L. lutra,* but the crown is not so broad or heeled as in *L. canadensis pacifica* (Plate 2, fig. 3). The principal cusp is heavier with the apex inclined backward, not vertical as in *L. lutra, L. canadensis pacifica,* or in *B. pristinus.* A posterior cuspule present in modern otters (Plate 2, fig. 2) and in *B. modicus* is absent in *Lutravus.*

$M\overline{1}$ is an elongate, relatively narrow tooth. The cingulum is less developed than in *L. lutra* or in *L. canadensis pacifica.* The anterior cusps rise gently to their apices from the cingulum which curves upward. In *L. lutra* and *L. canadensis pacifica* the cusps rise abruptly from a distinct ledge formed by the cingulum. The height of the crown is greater than in *Lutra.*

The protoconid is robust and the shearing blade is not deeply incised between this cusp and the paraconid. The paraconid is relatively narrow and is more in anteroposterior alignment with the protoconid. The metaconid is a much smaller cusp than in *Lutra lutra* or in *L. canadensis pacifica,* and it is more posterior in position and not so widely separated from the protoconid. The deep valley of the trigonid region, prominent in *L. lutra* and in *L. pacifica,* is not so evident in *Lutravus.* The talonid is small and not deeply basined. The anterior part of the tooth is much longer than the heel, while in *L. lutra* and in *L. canadensis pacifica* the heel is relatively much longer.

Although the type and referred specimen of *Lutravus halli* were not found in immediate association and doubtless belong to separate individuals, the occlusion of the cusps in $P\underline{4}$, $M\underline{1}$ and $M\overline{1}$ reveals an agreement which makes it seem probable, although not certain, that the two specimens belong to the same species.

Comparative Measurements (in millimeters) of $M\overline{1}$

	Lutravus Referred Specimen C.I.T. No. 643	Lutravus Referred specimen U.C. No. 22463	L. lutra C.I.T. No. 625	L. lutra*	L.c. pacifica Dickey Coll.
Greatest length at cingulum...	14.0	13.8	12.4	13.7	14.0
Greatest width at cingulum...	5.7	6.0	5.6	6.9	7.7
Greatest length of trigonid....	9.3	9.8	7.0	6.8	7.1
Greatest length of talonid.....	4.1	4.3	5.4	6.8	5.7
Greatest width of trigonid.....	5.0	5.9	4.8	5.8	6.2
Greatest width of talonid......	5.3	4.3	5.7	6.5	7.7

* Measurements from figured specimen, fig. 75, p. 360, G. S. Miller, *Catalogue of the Mammals of Western Europe,* 1912.

The lower teeth resemble in their characteristics the comparable teeth in otters, although, as may perhaps be expected, the lower dentition differs to a greater degree from that of the modern forms than does the upper dentition. Of minor importance but noteworthy nevertheless is the close agreement in size between Nos. 478 and 643.

In the occlusion of the lower and upper carnassials, the metaconid occupies the space between the protocone of $P\underline{4}$ and the anterior border of $M\underline{1}$ (Plate 2, fig. 7). The paraconid bites against the small basin of the protocone and the metaconid rests against the shelf encircling anteriorly the protocone of $M\underline{1}$. The relatively small basin of the talonid in $M\overline{1}$ receives the protocone of $M\underline{1}$, while the paracone and metacone in the latter tooth occlude perfectly with the slight grooves back of the protoconid on the outer margin of the hypoconid.

Although $M\overline{2}$ is not present, the position and direction of the alveolus for the tooth indicate that the crown would presumably triturate against the narrow hypoconal heel of $M\underline{1}$ (Plate 2, fig. 7).

The enamel of both the superior and inferior teeth is finely grooved, particularly on the outer surfaces of the sectorial teeth.

SKULL

The palate presents an approximately flat surface (Plate 1, fig. 5), not concave medially as in *L. canadensis pacifica* (Plate 1, fig. 8), in which respect a closer resemblance is seen to *L. lutra* (Plate 1, fig. 2). The surface is broken posteriorly, but enough of the bone remains beyond the molars to indicate that the palate terminated as far back as in *L. canadensis pacifica.*

Numerous small foramina pierce the palate as in *Lutra* and in *Mephitis.* The anterior palatine foramina are long, lobate in form, and lie in the course of the grooves that pass anteriorly from small paired foramina for the sphenopalatine nerves and vessels which pierce the palate to the inner side of the third premolars. In *L. canadensis pacifica* the anterior palatine foramina are relatively larger and approximately circular, and the small foramina are situated between the anterior margins of the fourth premolars. In *L. lutra* the anterior palatine foramina are sub-circular and relatively larger than in *Lutravus.* The palate in the latter genus is proportionately longer, with an average greater width than in *L. canadensis pacifica* and in *L. lutra.*

Comparative Measurements (in millimeters) of Palate

	Lutravus C.I.T. No. 478	L. lutra*	L. lutra C.I.T. No. 625	L.c. pacifica Dickey Coll. No. 18136
Long diameter from line between posterior margin of last molars to posterior border of incisive alveoli......	43.1	33.0	35.3	41.0
Transverse diameter between first molars..........................	17.0	12.0	13.0	18.7
Transverse diameter between fourth premolars.........................	19.4	15.2	12.6	16.3
Transverse diameter between second premolars.........................	16.0	12.7	11.7	14.2
Transverse diameter between canines...	14.0	13.5	13.8	15.5

* Measurements from figured specimen, fig. 74, p. 359, G. S. Miller, *Catalogue of the Mammals of Western Europe,* 1912.

The facial region (Plate 1, figs. 4, 6) exhibits characters of proportion that indicate less specialization resulting from a shortening and broadening of the muzzle and probably a greater dorsoventral diameter for the face. The maxillaries converge less abruptly toward the nasal suture line than in *L. lutra* (Plate 1, figs. 1, 3). In the maxillo-malar region the side of the face is higher than in modern forms, measuring 8.2 mm. from the edge of the alveolus of $P\underline{4}$ to the ventral margin of the infraorbital foramen. Comparable measurements for *L. lutra* and *L. canadensis pacifica* are 4.0 mm. and 4.5 mm., respectively.

Length of the muzzle is evidenced by the distance between the anterior margin of the opening of the postpalatine canal and the lateral margin of the nasal opening; 26.2 mm. in *Lutravus,* 20.1 mm. in *L. lutra* and 20.4 mm. in *L. canadensis pacifica.*

The maxillaries are not so widely expanded over the canine roots. The transverse diameter of the skull measured between the ends of the canine roots (22.3 mm.) is considerably less than in *L. canadensis pacifica* (27.7 mm.) and slightly less than in *L. lutra* (23.8 mm.). The diameter between the infraorbital foramina in *Lutravus* is 30.0 mm., in *L. canadensis pacifica* 28.3 mm., hence the face is seen to narrow anteriorly more decidedly in the Pliocene genus than in the living American otter. The same dimensions in the European species are more uniform, being 23.8 mm. between the canine roots and 24.0 mm. between the infraorbital foramina.

Lutravus (Plate 1, fig. 6) has a narrow anterior nasal orifice as in *L. lutra,* (Plate 1, fig. 3), while that in *L. canadensis pacifica* (Plate 1, fig. 9) is wide. Other differences of proportion are noted in the premaxillary region. In *Lutravus* the alveolar border is shallow and recedes from the incisor margin to the floor of the nares rather abruptly, whereas in *L. lutra* and in *L. canadensis pacifica* the surface has greater vertical height above the incisor border. The lateral ascending parts of the premaxillaries are more pronounced and are not inclined posteriorly so abruptly. Deep depressions are present on the surfaces of these elements.

Viewed from in front (Plate 1, figs. 3, 6, 9) the infraorbital foramina of *L. lutra* and *L. canadensis pacifica* are partly obscured by a lateral expansion of the maxillaries in the region of the alveoli for the canines. The infraorbital foramina and maxillo-malar region are fully exposed in *Lutravus.*

Lutravus, probably halli Furlong

The mustelid specimen, No. 22463 U. C. Coll., figured and described by Merriam, Stock, and Moody,[1] from the Rattlesnake formation of Oregon, Univ. Calif. locality 3045, is structurally very similar to No. 643 (Plate 2, fig. 4) from Thousand Creek. It consists of a portion of the right ramus and is more complete anteriorly than the Thousand Creek specimen, for remnants of $P\overline{2}$ and $P\overline{3}$ are present. In preservation and degree of wear, $P\overline{4}$ and $M\overline{1}$ are similar to the comparable teeth in No. 643. Likewise, as in the latter, $M\overline{2}$ is represented only by its alveolus.

The length of the cheek-tooth series appears to be comparable to that in No. 643. In the latter the length of the last premolar and first molar measures 21.4 mm., while in No. 22463 this measurement is 21.1 mm. $P\overline{2}$ is a double-rooted tooth of small size as in *L. lutra,* and is closely placed between the canine and $P\overline{3}$.

$P\overline{4}$ is crowded against $M\overline{1}$ as in No. 643, with like development of cingulum and attitude of cusp.

The cusps in $M\overline{1}$ differ only in minor details from those of No. 643. The protoconid and paraconid occupy the same relative positions. The apex of the metaconid is low as in No. 643 and does not form with the paraconid and protoconid the perfect trigonid with deep valley as in *L. lutra* (Plate 2, fig. 2) and in *L. canadensis pacifica* (Plate 2, fig. 3). The hypoconid is slightly more cuspate, the cingular border of the talonid protuberant, while in No. 643 the talonid is emarginate with steeper outer wall. The entoconid is absent in both the Thousand Creek and Rattlesnake specimens. The minor discrepancies may be due to individual or sub-specific variation. The first lower molars in the Thousand Creek and Rattlesnake specimens accord well in proportionate dimensions.

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[1] J. C. Merriam, Chester Stock, C. L. Moody, Carnegie Inst. Wash. Pub. No. 347, pp. 66, 67, fig. 18, 1925.

While the mental foramina are not to be noted in No. 643 because of incomplete preservation of the fore part of this specimen, the openings are clearly indicated in No. 22463. Certain characters can be noted from the latter. A large anterior mental foramen below P$\overline{2}$ and a small one below P$\overline{3}$ correspond to the foramina in *L. canadensis pacifica.* In the latter type the foramina have a position relatively farther posteriorly, the smaller one occurring below the anterior root of P$\overline{4}$. In *L. lutra* the foramina are not so widely spaced, the larger anterior one being situated below the anterior root of P$\overline{3}$ and the posterior foramen occurring as in *L. c. pacifica.* In *Lutravus,* specimen No. 643, the broken surface just anterior to the anterior root of P$\overline{4}$, shows a small canal, suggesting that the posterior mental foramen occupied a position anterior to P$\overline{4}$ and similar to that in Univ. Calif. No. 22463.

Comparative Measurements (in millimeters)

	Calif. Inst. Tech. No. 643	Univ. Calif. No. 22463
M$\overline{1}$, greatest length	14.0	13.8
M$\overline{1}$, transverse diameter	5.9	6.0
M$\overline{1}$, transverse diameter of trigonid	6.3	5.9
M$\overline{1}$, long diameter of trigonid	9.8	9.8
M$\overline{1}$, long diameter of talonid	4.0	4.3
M$\overline{1}$, height of crown at protoconid	8.0	7.5

The anterior margin of the masseteric fossa in *Lutravus,* Nos. 643 and 22463, terminates farther forward than in *L. c. pacifica* or in *L. lutra.* The ascending border of the coronoid process in Nos. 643 and 22463 is inclined dorsally more gradually than in *L. lutra* or in *L. c. pacifica.* In the latter species the ascending part rises abruptly above the horizontal ramus posterior to M$\overline{2}$.

Comparative Measurements (in millimeters) of Right Ramus

	Lutravus C.I.T. No. 643	Lutravus U.C. No. 22463	L. lutra*	L. lutra C.I.T. No. 625	L.c. pacifica Dickey Coll. No. 18136
Dorsoventral diameter of ramus at M$\overline{1}$	15.0	13.9	10.2	10.4	13.0
Transverse diameter at M$\overline{1}$	7.5	6.7	....	7.2	6.9

* Measurement from figured specimen, fig. 72, p. 357, G. S. Miller, *Catalogue of the Mammals of Western Europe,* 1912.

The ramus is somewhat convex ventrally below M$\overline{1}$ and P$\overline{4}$ and assumes a more even plane anterior to P$\overline{4}$ in the symphyseal region. This type of ventral border is seen in Nos. 643 and 22463. In *L. lutra* the convexity is less pronounced and in *L. c. pacifica* the ventral border of the entire ramus is continuously convex from symphysis to angle.

RELATIONSHIPS

The characters displayed in the superior and inferior dentition as well as by the skull of *Lutravus* clearly represent a stage in the phylogenetic development of the Lutrinæ earlier than that of the genus *Lutra.* The characters noted especially in the upper and lower carnassials and in $\mathrm{M}\underline{1}$ are distinctly less advanced than in modern representatives of the otter group. It is interesting to note that in a number of features, as for example in $\mathrm{P}\underline{4}$ and $\mathrm{M}\underline{1}$, *Lutravus* is more like the Quaternary European species *Lutra lutra* than like the Recent North American species *L. canadensis.* Perhaps the most striking of the more generalized characters to be seen in *Lutravus* relate to $\mathrm{M}\overline{1}$. This tooth differs from that in *Lutra* and in *Mephitis* in the more forwardly directed blade of the paraconid and in the posterior position of the metaconid. In these features greater resemblance prevails with *Meles meles, Martes martes* and *Mustela.*

Were it ultimately shown that the two specimens, on which the genus *Lutravus* is based, represent two distinct genera of mustelids rather than one and the same species the absence of more distinctive lutrine characters in $\mathrm{M}\overline{1}$ of No. 643 may indicate a relationship between this specimen and *Sthenictis.*

Largely because of the fragmentary nature of the remains, the otters described from the European Miocene and Pliocene with the possible exception of *Pothamotherium,* are of uncertain generic status. On the other hand, at least two Quaternary and late Tertiary species of the Old World, namely *Lutra lutra* and *L. palæindica,* appear to be definitely established. Among the fossil forms recorded from North America, the type of *Lutravus* is now known also from the Rattlesnake Pliocene of the John Day basin, Oregon. The presence of this species in the Thousand Creek and Rattlesnake furnishes incidentally further evidence of the close relationship of these two faunas, already indicated by presence of identical or nearly related species of *Hipparion* and *Sphenophalos.*

The structural characters exhibited by *Lutravus* and the position of this genus in the later Tertiary of western North America obviates the possibility of deriving the form definitely from some specific member of the more generalized mustelids of the earlier Tertiary. Certain it is that more information is needed concerning the Miocene representatives of the group.

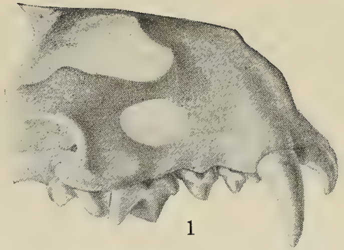
PLATE 1

All figures natural size.

FIGS. 1, 2, 3—*Lutra lutra* Linnæus. C.I.T. No. 625, Recent, England. Lateral, ventral and anterior views of skull.

FIGS. 4, 5. 6—*Lutravus halli* n. gen. and n. sp. Type C.I.T. No. 478, Thousand Creek Pliocene, Nevada. Lateral, ventral and anterior views of skull.

FIGS. 7, 8, 9—*Lutra canadensis pacifica* Rhoads. Dickey Coll. No. 18136, Oregon. Lateral, ventral and anterior views of skull.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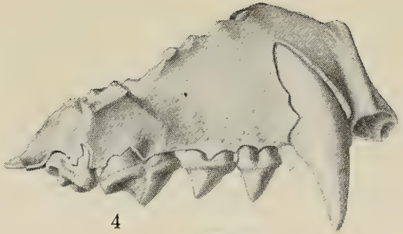
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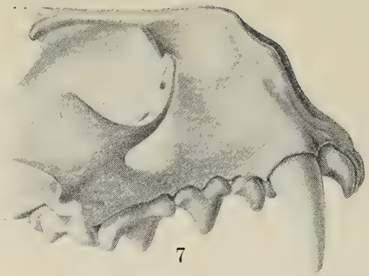
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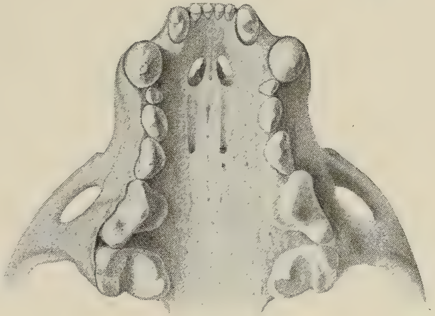
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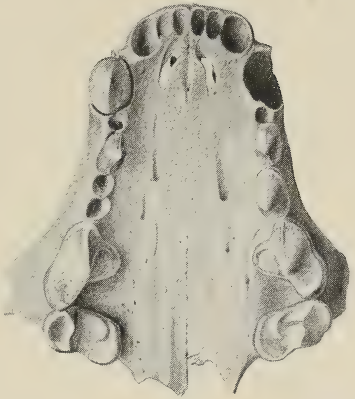
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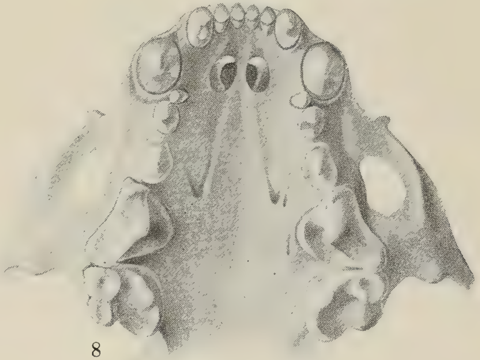
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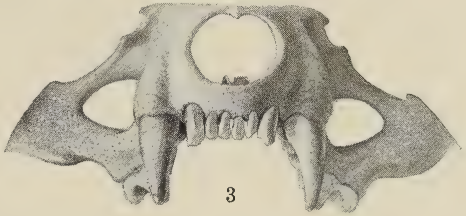
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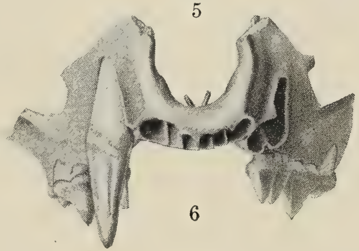
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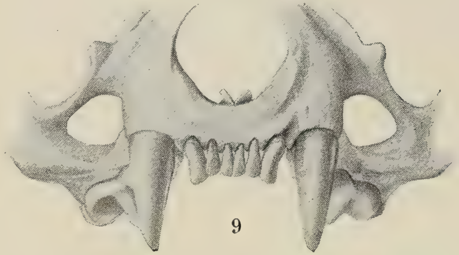
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Plate 2

All figures natural size.

Fig. 1—*Lutravus,* probably ***halli*** Furlong. Univ. Calif. No. 22463, Rattlesnake Pliocene, Oregon. Lateral and dorsal views of ramus.

Fig. 2—*Lutra lutra* Linnæus. C.I.T. No. 625, Recent, England. Lateral and dorsal views of ramus.

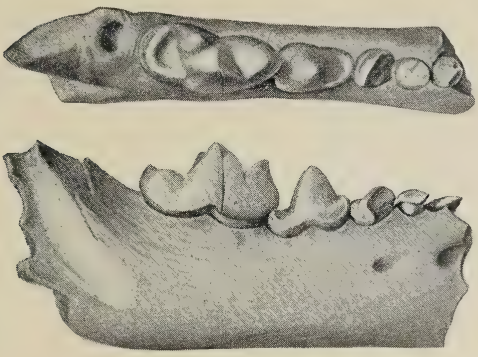
Fig. 3—*Lutra canadensis pacifica* Rhoads. Dickey Coll. No. 18136, Recent, Oregon. Dorsal and lateral views of ramus.

Fig. 4—*Lutravus* ***halli*** n. gen. and n. sp. Referred specimen, C.I.T. No. 643, Thousand Creek Pliocene, Nevada. Dorsal and lateral views of ramus.

Fig. 5—*Lutravus* ***halli*** n. gen. and n. sp. C.I.T. Nos. 478-643, Thousand Creek Pliocene, Nevada. Outer view of inferior and superior teeth in occlusion.

Fig. 6—*Lutravus* ***halli*** n. gen. and n. sp. C.I.T. Nos. 478-643, Thousand Creek Pliocene, Nevada. Inner view of inferior and superior teeth in occlusion.

Fig. 7—Diagram showing relationships of cusps in $M\overline{1}$, $M\overline{2}$, $P\underline{4}$ and $M\underline{1}$ of *Lutravus* when teeth occlude, 1 Paraconid, 2 Protoconid, 3 Hypoconid, 4 Metaconid. Position of metaconid should be farther forward than indicated.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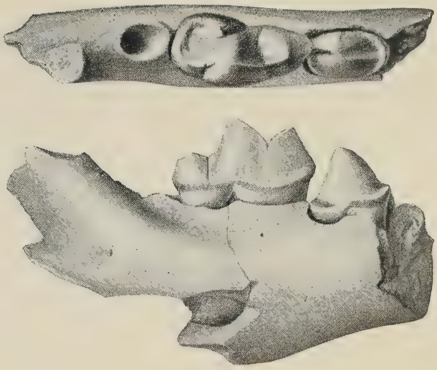
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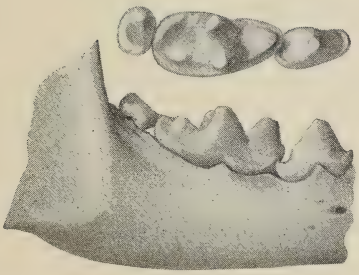
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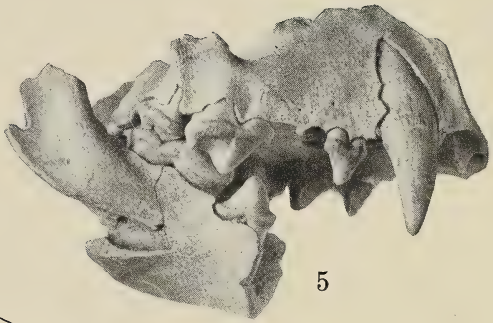
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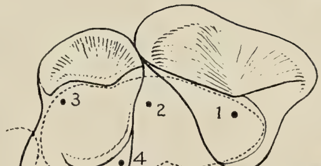

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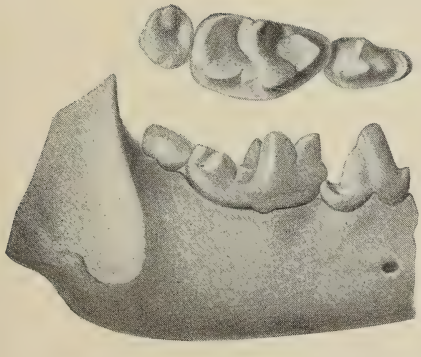
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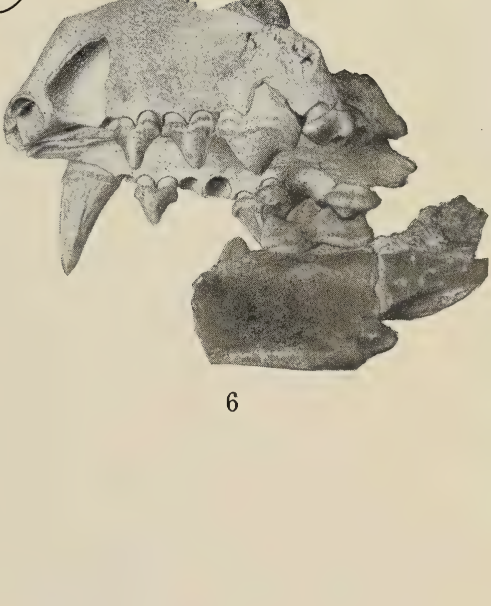
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VI

A CONTRIBUTION TO THE PALEOZOIC GEOLOGY OF CENTRAL OREGON

By E. L. Packard

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A CONTRIBUTION TO THE PALEOZOIC GEOLOGY OF CENTRAL OREGON

Several areas of fossiliferous upper Paleozoic rocks were unexpectedly discovered in 1926 by the writer and the members of the University of Oregon Geological Field Party. These old rocks occur along the headwaters of Grindstone Creek, Twelve Mile Creek, South Fork of Beaver Creek, all tributaries of the upper Crooked River, and within the drainage basin of South Fork of John Day River.

The first Paleozoic fossils to be discovered in eastern Oregon were apparently found by Thomas Condon. Lindgren,[1] writing on the Goldbelt of the Blue Mountains of Oregon, stated that "well-defined Carboniferous fossils" from the "Crooked River drainage" had been found by Condon. Those specimens have not been recognized among the Condon collections of the University. Chester Washburne [2] reported Paleozoic fossils on Beaver Creek, Grant County, along the old Prineville-Izee road. Those specimens were submitted to Dr. George H. Girty for determination. Only two proved to be Paleozoic, and one was referred to the genus *Zaphrentis* with the statement that it indicated "Carboniferous, though it may, in fact, be Devonian." [3] Howard Powers, while collecting Cretaceous fossils along Beaver Creek under the writer's direction, discovered fossiliferous limestone boulders in the alluvium of South Fork of Beaver Creek.

A year later the writer and his assistants discovered important exposures on Grindstone and Twelve Mile Creeks containing a typical Baird Carboniferous fauna, including the species *Productus striatus* Fischer, determined through the courtesy of Dr. Charles Schuchert. [4]

This region of Paleozoic and Mesozoic outcrops lies within a vast window cut through Tertiary lavas and tuffs that form the southward sloping block of the Ochoco Range. This portion of central Oregon, covering parts of Crook, Grant, and Harney Counties, extends from R. 24 E. to 32 E. and lies within the townships 17 and 18 S. It has not been mapped topographically, and therefore many details of stratigraphy must await completion of a geologic map. It is, however, desirable to place on record such geologic and paleontologic data relating to the Paleozoic as are now available.

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[1] Waldemar Lindgren, *Goldbelt of the Blue Mountains of Oregon,* U. S. Geol. Surv. 22d Ann. Report, pt. 2, p. 579, 1901.

[2] Chester Washburne, *Notes on the marine sediments of eastern Oregon,* Jour. Geol., vol. 11, pp. 224-229, 1903.

[3] Chester Washburne, *op. cit.,* p. 226.

[4] Personal communication.

The Paleozoic outcrops of this general region occur within three isolated areas that may be designated the Suplee, the Beaver Creek, and the Big Flat areas.

The Beaver Creek area, although the smallest of the three, will be mentioned first since it probably was the only Paleozoic in this region known to geologists prior to 1926. This area includes several small exposures totaling only a few acres in extent. The larger of these occur as conspicuous knobs within the narrow valley of South Fork of Beaver Creek about half a mile above the Bernard Ranch house, which is situated in sec. 13, T. 17 S., R. 25 E. The largest exposure lies in fault contact on the north with upper Cretaceous, but it is otherwise surrounded by basal beds of the younger of two Triassic formations recently studied by Edward Schenk.[1] It forms a small rounded hill capped with crags of limestone. Near the top is a fine-grained, dark gray limestone, weathering to a very light gray. In places irregular masses of chert are scattered through the badly checked limestone, resulting in very irregular weathering surfaces. Interbedded with these cherty limestones along the lower slopes of the hill are irregular lenses of cherts several inches in thickness which trend northeasterly and dip steeply. The southwesterly projection of the strike line of these chert bands enters the area and parallels the strike lines of the Paleozoic at its most important locality southwest of Suplee Post Office.

The smaller and easternmost knob of Paleozoic on South Fork of Beaver Creek is composed of a similar limestone, but unlike the larger area this exposure has not been proven to be fossiliferous. Its structure is not clearly determinable, but it probably is a part of the same structure described above. Both of these limestone masses were overlain by basal Triassic conglomerates from which the numerous fossiliferous boulders strewn over the valley floor were evidently derived, and which may have yielded Condon, Washburne, and finally Powers the small faunas reported by them.

The larger of these areas has recently yielded a meager fauna including *Productus striatus* Fischer, thus permitting a correlation with rocks containing the same fauna described below from the Suplee area.

The second major area of Paleozoic outcrops occurs on Big Flat, probably in sec. 2, T. 18 S., R. 27 E., just within the western edge of the drainage basin of South Fork of John Day along the southernmost of the two old Suplee-Izee roads. The known exposures of these old rocks are there confined to a small rounded hill rising about 100 feet above the road crossing Big Flat. The most conspicuous mass occurs as a limestone crag some 8 feet high, 50 feet long, and 20 feet wide, standing like the ruins of an old fort at the top of the hill. These rocks include two massive beds of dark gray limestone weathering to a light gray, and each from 8 to 10 feet in thickness, separated by about 15 feet of thin-bedded, shaly limestone forming the "floor of the fort." A smaller mass occurs to the south at the base of the same hill, but since it has not yielded recognizable fossils, its assignment to the Paleozoic is now tentative.

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[1] Edward Schenk, A master's thesis, University of Oregon, 1930.

The limestones at the top of the hill strike nearly east and west and dip nearly vertically. They are unconformably overlain by the older of two Triassic formations recently recognized by Schenk.[1] Small masses of the Triassic basal conglomerates occur on the slopes of this hill, and they consist of limestone and chert boulders reaching diameters as great as two feet. The limestones are highly fossiliferous, containing numerous specimens of foraminifera, corals, and round crinoid stems.

Dr. Hubert Schenck [2] recognized the Permian affinities of fusulinids occurring in these pebbles several years ago, and recently Mr. Harry Wheeler, working with new material, has been able to recognize species of *Schwagerina,* confirming the earlier determination by Schenck. As yet this foraminiferal fauna has been obtained only from limestone boulders derived from basal Triassic conglomerates. The large size of the boulders, which equal a foot or two in diameter, precludes their transportation any great distance. That fauna may later be found in place near by, and might possibly be represented by the meager fauna from the large exposure at the top of the hill, although as yet foraminifera have not been discovered at that outcrop.

The largest and most important area of highly fossiliferous Paleozoic rocks occurring within Oregon lies southwest of Suplee in the drainage basins of Grindstone and Twelve Mile Creeks, both of which are headwaters of Crooked River. More than 10 square miles of these old rocks are exposed as a strip trending northeasterly from sec. 13, T. 19 S., R. 24 E. at least as far as sec. 20, T. 18 S., R. 25 E. This strip is not less than two miles wide and is the widest at the northern end. The rounded hills, comprising this area, with their occasional crags of cherty limestone, contrast strongly with the topography of the long northeasterly trending strike ridges of the Mesozoic formations lying to the southward and eastward. A still more conspicuous topographic unconformity occurs between this Paleozoic area and the flat-lying Tertiary lavas and tuffs exposed to the north and west.

The most conspicuous exposure at the southern end of this belt of old rocks is locally known as Tucker Butte and is situated in sec. 18,

[1] Edward Schenk, *op. cit.*, p. 6.

[2] Personal communication.

T. 19 S., R. 25 E. Other small conical shaped buttes occur a mile or more to the westward farther down the valley of Twelve Mile Creek. Crags of limestones also occur near an old school to the northeast in upper Twelve Mile valley, and many others rise above the level of the grass-covered rounded hills to the northward, extending over the low divide beyond Grindstone Creek.

Tucker Butte is a conspicuous limestone strike ridge about half a mile long, over 200 feet high and trending north 70° east. The northwestern side is precipitous, where at least 100 feet of massive limestones are exposed in cliff section. The beds dip steeply southward. The impure limestones forming the crest of the ridge are dark gray in color and contain chert masses which accentuate the irregularities of the weathered surfaces. A short distance below the top, on the gentler slope of the southern side, thin-bedded, tan-colored, fossiliferous limestones, interbedded with brecciated banded cherts, are exposed. At the base of the cliff on the steep northern side a series of cherts and quartzites, badly fractured, apparently metamorphosed, and appearing to lie unconformably below the limestones, is exposed. If these prove upon detailed investigation to be older than the limestones, they will represent the oldest rocks of the area.

The most complete section will be obtained at the northern end of the Paleozoic outcrops eastward from sec. 30, T. 18 S., R. 25 E. Continuous outcrops are not obtainable, but detailed mapping not yet accomplished will show the presence of several thousands of feet of limestones, banded cherts, and thin-bedded impure limestones. The lowest beds of this eastward dipping series occur near the eastern line of section 30, where they consist of brecciated gray limestones containing irregular masses of gray chert, massive, veined, gray limestones, and thin-bedded impure limestones alternating with bands of chert. The brecciated limestones form the more conspicuous exposures further south toward Grindstone Creek. This rock is composed of large subangular blocks of limestone and fragments of gray-banded chert. These brecciated masses appear to be lenticles in thin-bedded limestones and cherts, for they are not traceable for more than 200 feet along their strike. They seem to be confined to the lower 500 feet of the section.

Above this zone of brecciated limestones is a series of lighter colored thin-bedded limestones alternating with layers of cherts which are seldom more than 6 inches in thickness. The cherts comprise approximately 50 per cent of the rocks of this portion of the section. The exposures are scattered over the slopes of the rounded hills, but much fragmental material at the surface shows cherts of brown, gray, black, or variegated colors. Some beds of these rocks are nearly colorless, and an occasional specimen shows a coral or crinoid stem replaced by the silica. Still higher in the series in sec. 27 or 28, T. 18 S., R. 25 E. on a small tributary of Grindstone Creek and outside of "Sage Hen Reserve" is a large cliff section representing 100 feet or more of cherts which constitute more than 75 per cent of the rocks. There the chert bands averaging about 4 inches in thickness are separated by thin calcareous layers. These cherts are badly fractured and now lie in a jumbled mass. This may be the result of faulting, for these beds appear to strike into a strike ridge trending nearly north and south and terminating in a conspicuous fossiliferous massive limestone, outcropping near the road along Grindstone Creek. Limestone crags extend for nearly a mile eastward across the strike, but the grass-covered areas give but an imperfect knowledge of the section, and the true thickness is as yet unknown.

The large majority of dips within this Suplee area are to the eastward. Westward dips have been found only at the northern end of the Paleozoic exposures. The dips are all steep, those to the east usually exceeding 50 degrees. The lesser number of westward dips are of the same order. Nearly all of the strikes trend northeast 70 to 80 degrees, except at the southern end on Tucker Butte where they shift farther eastward. It thus appears that the major structure of these Paleozoic rocks is anticlinal and extends at least from sec. 13, T. 19 S., R. 24 E. northeasterly to about the center of sec. 30, T. 18 S., R. 25 E.

There is no positive proof as yet of beds older than those containing the *Productus striatus* fauna. Certain beds, however, exposed at the northern base of Tucker Butte, appear to be more indurated and may represent an older series. The possibilities of discovering an unconformity within these Paleozoic rocks will not be exhausted until after the stratigraphy and paleontology have been more completely investigated.

These rocks are unconformably overlain by Mesozoic marine sediments and are in contact, at least, with basic igneous rocks of Tertiary age on Coffee Creek at the northern end of the structure.

During the season of 1926 collections of Paleozoic were made at several localities within this portion of central Oregon, but a systematic study of the fauna has not yet been attempted. The largest collections so far obtained came from a University of Oregon locality on upper Coffee Creek within the Suplee area.

Dr. Charles Schuchert kindly examined a tray of specimens from that locality and recognized such diagnostic forms as *Productus near giganteus* Martin, *Productus cf. striatus* Fischer, *Spirifer cf. striatus* Martin, and other Baird Mississippian brachiopods, corals, bryozoans, and mollusks. In a brief note[1] the writer reported this discovery among others in the same region. This fauna was first found in low beds on the presumed western limb of the Suplee Paleozoic anticline. About half a mile eastward in limestone cliffs, representing the eastern limb of the same structure, a fauna occurs which is similar except for the lack of the large brachiopod. *Productus striatus* Fischer has been found there and at several localities to the eastward nearly as far as the heavy chert zone described above from sec. 27 or 28, T. 18 S., R. 25 E. The uppermost portion of the same section has not yet yielded determinable fossils.

The Tucker Butte fauna appears also to belong to the *P. striatus* zone, as does the meager collection from Beaver Creek area where specimens of that characteristic species have been found.

As yet the Big Flat limestone fauna has not been definitely correlated with the *P. striatus* fauna, and therefore its age is still uncertain. The only forms so far determined from that region are the fusulinids reported by Dr. Hubert Schenck and Mr. Harry Wheeler. These indicate a Permian age of the basal Triassic boulders in which they occur, and, as discussed above, are tentatively assigned to that period.

The recognition of the Baird fauna has led to a study of the two forms, *Productus giganteus* and *P. striatus.* The specimens from a locality on Coffee Creek referred to *Productus giganteus* are all fragmentary, but they indicate a brachiopod not less than 9 inches in breadth. The form was compared with a specimen from the Baird [2] of Shasta County, California, and it was found to be identical as far as it was possible to compare the specimens. The ribbing of the Oregon specimens shows the same slightly wavy character with the relatively wide interspaces, and has the same character of the inner layer as found on the Californian specimens. However, the largest, fragment, as well as numerous smaller ones from Oregon, representing about one-third of an individual, lacks the conspicuous irregular flutings of the typical European species, as shown on forms from Denbeigh, Ireland, kindly loaned by Dr. Schuchert. The western specimens also show other differences worthy of note. Flutings appear on the Ireland specimen at a distance about 110 mm. from the beaks, but none are observable on the Oregon specimens even at a much greater distance from the beak. Those found from the west have fine radial ribs showing, even on the larger specimens, only a slight tendency to waviness, whereas the Ireland specimen shows a most striking irregularity of the ribs which twist and turn abruptly over the disk and umbonal region. The concentric growth lines are quite regular on the Oregon specimens examined, whereas they are exceedingly irregular on the European form. The inner layer of the Oregon form shows an irregular arrangement of nodes, differing again from the European form with its more orderly arranged nodose ribs. A comparison of specimens from Oregon with those from the type Baird indicate that the large productid listed as *giganteus* from the Baird, Mississippian Carboniferous of California, is represented in central Oregon. But the differences from the typical European species of *giganteus,* however, suggest the presence of a new species common to Oregon and California.

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[1] E. L. Packard, *A new section of Palæozoic and Mesozoic rocks in central Oregon,* Amer. Jour. Sci., vol. 15, p. 323, Mar. 1928.

[2] C. A. White, *Contributions to Invertebrate Paleontology, No. 6, Certain Carboniferous fossils from the Western States and Territories,* U. S. Geog. Sur. Terr. (Hayden), Ann. Report 12, pt. 1, p. 132, 1883.

The species *Productus striatus* Fischer is represented by a number of specimens, none of which is entire, but several of which, nevertheless, show the essential diagnostic characters of that species. The Oregon specimens were compared to Belgium specimens from the Peabody Museum.

The only external differences between the European specimens and those from Oregon seem to be in the details of the ribbing and in the thickness of the shell. The Oregon specimen has somewhat coarser and less tabulate ribs. The shell of the Oregon specimen is also somewhat thicker than that of the specimens of *P. striatus* examined; otherwise the two forms seem to be externally identical in shape, convexity, and size and probably are no further apart than two geographic varieties.

These areas of upper Paleozoic rocks afford the most extensive sections of fossiliferous rock known from Oregon, and their detailed geologic investigation will greatly enrich the Paleozoic history of the state.

The fauna is known to contain a varied assemblage of Baird types and includes the well-known *Productus striatus* Fischer. Specimens of a giant brachiopod found in this Suplee region are specifically identical with specimens from the type Baird, but these may prove specifically distinct from typical specimens of *P. giganteus* Martin. This fauna is, therefore, worthy of a special investigation, and detailed faunal studies in this central Oregon region may reveal other younger Paleozoic faunas.

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